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ABSTRACT

This volume contains the papers presented at a workshop which brought together authorities from several different disciplines, each working in the area of natural language analysis, to participate in intensive, technical discussions of the issues involved in developing adequate grammars and semantics of natural languages. The disciplines represented were linguistics, philosophy, and psychology. Introductory remarks provide details on workshop procedures and participants. The 19 papers presented at the workshop are included in the main part of the document. [Not available in hard copy due to marginal legibility of original document.] (VM)

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RESEARCH WORKSHOP REPORT

GRAMMAR AND SEMANTICS OF NATURAL LANGUAGES

Stanford University
Stanford, California

September 17-19, 1970
and
November 20-21, 1970

Sponsored by the

COMMITTEE ON BASIC RESEARCH IN EDUCATION
DIVISION OF BEHAVIORAL SCIENCES
NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL

and the

NATIONAL ACADEMY OF EDUCATION

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Workshop Director: Dr. Patrick Suppes, Stanford University
Workshop Coordinator: Dr. Elizabeth Gammon, Riverside County School System

February 1971

COBRE Research Workshop on

GRAMMAR AND SEMANTICS OF NATURAL LANGUAGES
Palo Alto, California
September 19-21, 1970
November 20-21, 1970

WORKSHOP REPORT "GRAMMAR AND SEMANTICS OF NATURAL LANGUAGES" by Elizabeth Gammon.

1. "On Sentence Stress and Syntactic Transformations" by Joan W. Bresnan
2. "On the Problem of Subject Structure in Language with Application to Late Archaic Chinese" by Chung-ying Cheng
3. "A Proposal Concerning Question-Words" by Teresa M. Cheng
4. "Computing and Case Grammar" or "Remarks on the Attempted Application of a Computer Program for Aspects to an Attempted Lexicalist-case Grammar for English" by Joyce Friedman
5. "Some Tables from A Syntactical Analysis of Some First-Grade Readers" by Elizabeth Gammon
6. "Identifiability of Transformational Grammars" by Henry Hamburger
7. "Grammar and Logic: Some Borderline Problems" by Jaakko Hintikka
8. "Dthat" by David Kaplan
9. "Reference Materials for Quantification in Ordinary English" by Richard Montague
10. "The Problem of the Semantics of Mass Terms in English" by Julius Moravcsik
11. "The Concept of Unit in Child Grammar" by Arlene I. Moskowitz
12. "Intensional Isomorphism and Deep Structure" by Barbara Hall Partee
13. "On Restricting the Base Component of Transformational Grammars" by Stanley Peters, Jr. & R. W. Ritchie
14. "Comments on Montague's Paper" by Patrick Suppes
15. "Semantics of Context-free Fragments of Natural Languages" by Patrick Suppes
16. "Comments on Julius Moravcsik's Paper" by Elizabeth Traugott
17. "On the Insufficiency of Surface Data and the Learning of Transformational Languages" by Kenneth Wexler & Henry Hamburger

Prepared by

Elizabeth Gammon, Workshop Coordinator

Summary Report on the Workshop on Grammar and Semantics of Natural Languages

The workshop on Grammar and Semantics of Natural Languages was held at Stanford University under the general chairmanship of Professor Patrick Suppes; Professors Jaakko Hintikka and Julius Moravcsik collaborated in the organization, and Dr. Elizabeth Gammon served as workshop coordinator. The purpose of the workshop was to bring together authorities from several different disciplines, each of whom is working in the area of natural language analysis. The hope was that through intensive and reasonably technical discussions of the issues involved in developing adequate grammars and semantics of natural languages, the participants would exchange ideas not only within but across disciplines. The major disciplines represented were linguistics, philosophy and psychology.

The workshop was held in two sessions; the first session met on September 17-19, 1970, and consisted mainly of the presentation of papers. The second session met approximately two months later on November 20-21. The reason for the two sessions was to allow the participants time to reread the papers presented at the first session and to prepare comments on them for discussion at the second session.

Nineteen people were invited to present papers and five others were invited as participants. Both sessions were open to the community in general, so most of the meetings were attended by forty or fifty people. The following is a list of the invited participants, their affiliations, and the titles of the papers they presented.

Participants who presented papers

Miss Joan Bresnan Department of Linguistics and Foreign Languages Massachusetts Institute of Technology	"On Sentence Stress and Syntactic Transformations"
Dr. Chung-ying Cheng Department of Philosophy University of Hawaii	"On the Problem of Subject Structure in Language with Application to Late Archaic Chinese"
Mrs. Teresa M. W. Cheng Department of Linguistics University of Hawaii	"A Proposal Concerning Question-words"
Professor John M. Dolan Department of Philosophy The Rockefeller University	"Translation, Rationality, and Complexity"
Professor Joyce Friedman Department of Computer and Communication Sciences University of Michigan	"Computing and Case Grammar"
Dr. Elizabeth Gammon Instructional Services Riverside County School System	"A Syntactic Analysis of Some First-Grade Readers"
Professor Henry Hamburger School of Social Sciences University of California at Irvine	"Identifiability of Transformational Grammars" (with Wexler)
Professor Jaakko Hintikka Department of Philosophy Stanford University	"Grammar and Logic: Some Borderline Problems"
Professor David Kaplan Department of Philosophy University of California at Los Angeles	"DTHAT"
Professor Donald Knuth Department of Computer Science Stanford University	"Examples of Formal Semantics"

(Participants who presented papers, continued)

Professor Richard Montague Department of Philosophy University of California at Los Angeles	"The Proper Treatment of Quantification in Ordinary English"
Professor Julius Moravcsik Department of Philosophy Stanford University	"The Problem of the Semantics of Mass Terms in English"
Miss Arlene Moskowitz Department of Linguistics University of California at Berkeley	"The Concept of Unit in Child Grammar"
Professor Barbara Hall Partee Department of Linguistics University of California at Los Angeles	"Intensional Isomorphism and Deep Structure"
Professor Stanley Peters Department of Linguistics The University of Texas at Austin	"On Restricting the Base Component of Transformational Grammars" (with Ritchie)
Dr. R. W. Ritchie Vice Provost for Academic Administration University of Washington	"On Restricting the Base Component of Transformational Grammars" (with Peters)
Professor Patrick Suppes Department of Philosophy Stanford University	"Semantics of Context-free Fragments of Natural Languages"
Professor W. C. Watt School of Social Sciences University of California at Irvine	"Late Lexicalizations"
Professor Kenneth Wexler School of Social Sciences University of California at Irvine	"On the Insufficiency of Surface Data for the Learning of Transformational Languages" (with Hamburger)

Special Observers

Professor Herbert H. Clark
Department of Psychology
Stanford University

Professor Charles Ferguson
Chairman, Committee on Linguistics
Stanford University

Dr. Charles Fillmore
Center for Advanced Study in
the Behavioral Sciences
Stanford

Dr. William Kruskal
Center for Advanced Study in
the Behavioral Sciences
Stanford

Dr. Elizabeth C. Traugott
English Department
Stanford University

Those participants who needed motel reservations stayed at Rickeys Hyatt House in Palo Alto. The meetings were held on the Stanford campus, those for the first session in the lecture room of Polya Hall and those for the second in the seminar room of Ventura Hall. Four cars were rented to be shared by the participants for local transportation.

The programs for the two sessions were as follows:

September Session

Thursday, September 17

Morning Session, 10:00 a.m. - 12:00 noon

Chung-ying Cheng	On the Problem of Subject Structure in Language with Application to Late Archaic Chinese
Elizabeth Gammon	A Syntactical Analysis of Some First-Grade Readers

Afternoon Session, 2:00 p.m. - 5:00 p.m.

John Dolan	Translation, Rationality, and Complexity
David Kaplan	DTHAT
Jaakko Hintikka	Grammar and Logic: Some Borderline Problems

Friday, September 18

Morning Session, 9:00 a.m. - 12:00 noon

Teresa Cheng	A Proposal Concerning Question-words
Joan Bresnan	On Sentence Stress and Syntactic Transformations

Afternoon Session, 2:00 p.m. - 5:00 p.m.

Patrick Suppes	Semantics of Context-Free Fragments of Natural Languages
Richard Montague	The Proper Treatment of Quantification in Ordinary English
Julius Moravcsik	The Problem of the Semantics of Mass Terms in English

Saturday, September 19

Morning Session, 9:00 a.m. - 12:00 noon

H. Hamburger - K. Wexler	Identifiability of Transformational Grammars
K. Wexler - H. Hamburger	On the Insufficiency of Surface Data for the Learning of Transformational Languages
W. C. Watt	Late Lexicalizations

Afternoon Session, 2:00 p.m. - 5:00 p.m.

Joyce Friedman	Computing and Case Grammars
Barbara Hall Partee	Intensional Isomorphism and Deep Structure
Arlene Moskowitz	The Concept of Unit in Child Grammar

November Session

Friday, November 20

10:00 a.m. - 12:30 p.m.	Discussion led by D. Knuth, followed by discussions of papers by P. Suppes and E. Gammon
2:00 p.m. - 5:00 p.m.	Discussions of papers by J. Dolan, J. Hintikka, D. Kaplan, R. Montague, J. Moravcsik, and B. Partee

Saturday, November 21

9:00 a.m. - 12:00 noon	Discussions of papers by C. Cheng, T. Cheng, Hamburger-Wexler, and A. Moskowitz
2:00 p.m. - 5:00 p.m.	Discussion led by S. Peters and R. Ritchie, followed by discussion of papers by J. Bresnan, J. Friedman, and W. Watt

A summary of each of the papers presented is given below. The complete papers as well as comments on them written by the other participants will appear in a volume of the proceedings to be published by D. Reidel Publishing Company.

Professor Cheng presented a discussion of the distinction between subject and predicate, and then showed that based on this distinction subject-predicate structures in Late Archaic Chinese can be systematically illustrated and logically explained. He suggested such an explanation for the subject structure involving four levels of analysis; the levels concern the presence or absence of ontic subject and logical subject in the deep structure and the presence or absence of grammatical subject and topic or comment in the surface structure. The application of this analysis to Late Archaic Chinese was illustrated with several examples.

Dr. Gammon presented some probabilistic grammars for two first-grade readers. She explained the difficulties involved in writing such grammars for a large and irregular corpus and showed how some of the difficulties could be handled.

Professor Dolan discussed the problems of translation from the standpoint of Quine's Word and Object.

Professor Kaplan discussed denoting phrases, especially the word "that" when used with a physical gesture such as pointing. He examined the viewpoint that some or all of the denoting phrases used in an utterance should not be considered part of the content of what is said but should rather be thought of as contextual factors which help interpret the actual physical utterance as having a certain content.

Professor Hintikka discussed applications of modal logic which he felt to be of mutual interest to linguists and logicians. In particular he discussed the use of "possible worlds" to elucidate the semantics of modality and pointed out some of the misconceptions linguists have held in using this approach.

Mrs. Teresa Cheng challenged the structuralist's assumption regarding the completeness and autonomy of a sentence. She then discussed some possible motives and constraints for transformational operations and related this to a proposal concerning the central role played by questions in the semantics of natural language.

Miss Joan Bresnan showed that if the Nuclear Stress Rule of English is ordered within the transformational cycle after all of the syntactic transformations, many apparent exceptions to some of Chomsky's and Halle's assertions are predictable because the stress patterns of certain syntactically complex constructions reflect those of the simple sentences embedded within them in deep structure. This preservation of basic stress pattern through the syntactic derivation provides a new method of determining underlying grammatical representations and deciding questions of syntax. Miss Bresnan discussed the consequences of this for linguistic theory, in particular Chomsky's lexical versus transformational hypothesis.

Professor Suppes combined the viewpoints of model-theoretic semantics and generative grammar and provided a formal definition for the semantics of context-free languages. He then applied the results to some fragments of natural languages, particularly to the corpus of speech of a young child.

Professor Montague presented in a rigorous way the syntax and semantics of a particular fragment of a certain dialect of English. The fragment was made as simple and restricted as possible while accommodating many of the more puzzling cases of quantification and reference.

Professor Moravcsik explored the semantics and syntax of mass terms and discussed the issue of how an adequate treatment could be incorporated into a general theory of English. He provided a comparison and some criticisms of the proposals for the semantics of mass terms which have been given by Quine and by Parsons and then presented a proposal of his own and showed how it met the criticisms he raised.

Professors Hamburger and Wexler presented two joint papers. The first extended a formal theory of language learning to transformational components; learning procedures which are psychologically more suggestive than those previously studied were shown to yield positive results under formally specified conditions. The second paper discussed the concept of identifiability in the limit with special reference to transformational languages on a given base. Counterexamples, that is, context-free grammars for which the set of transformational languages is not identifiable, were also exhibited.

Professor Watt presented facts about certain English words (similar to Postal's "Anaphoris Islands") which, on the whole, support the view that those words are more naturally treated in a "Transformationalist" grammar than in a "Lexicalist" one. The words appear to be the result of late rather than early lexicalization; that is, they appear to be inserted near the surface instead of at a much deeper level corresponding to the last stage of the generation of the base phrase-marker.

Professor Friedman described an application of a computer model of transformational grammar based on Chomsky's Aspects to a grammar based in part on more recent theories, in particular the lexicalist and case theories. The computer system is one written at Stanford a few years ago and described in the CACM, June 1969, and Friedman et al. (forthcoming). The grammar is the UCLA English Syntax Project grammar, written primarily by Stockwell, Schachter, and Partee and described in a two-volume unpublished report.

Professor Partee investigated the mutual relevance of some formal semantical notions developed by Carnap and the natural-language syntactic theory developed by Chomsky and suggested some possible modifications of each. The problem considered was the analysis of sentences whose main verbs take as objects or complements sentences or propositions, and in particular, the question of how closely the meaning of such a sentence is tied to the linguistic form of the embedded sentence.

Miss Arlene Moskowitz discussed an approach to the study of language acquisition data in terms of units appropriate to the child's dynamic linguistic system. She described the application of her ideas to both phonology acquisition and syntax acquisition.

Professor Knuth discussed the way in which meaning may be assigned to a string in a context-free language by defining attributes of the symbols in a derivation tree for that string; the attributes can be defined by functions associated with each production in the grammar. He then examined the implications of this process when some of the attributes are "synthesized," that is, defined solely in terms of attributes of the "descendants" of the corresponding nonterminal symbol, while other attributes are "inherited," that is, defined in terms of attributes of the "ancestors" of the nonterminal symbol.

Professors Peters and Ritchie presented a joint paper in which they investigated the effects of placing various restrictions on the base component of a transformational grammar as defined by Chomsky. They showed that by utilizing the so-called filter function of transformations the descriptive power of transformational grammars can be preserved unreduced even when their base components are subjected to drastic restrictions.

There was much animated discussion of the papers especially by the philosophers and linguists. One of the most useful comments for reaching across disciplines was a comparison Barbara Partee made of Montague's scheme for syntactic and semantic analysis with one a linguist might make.

Overall, the workshop served its purpose of bringing about an exchange of the most recent ideas concerning the syntax and semantics of natural languages both within and across the disciplines of linguistics, philosophy and psychology.

On sentence stress and syntactic transformations

Joan W. Bresnan

Massachusetts Institute of Technology

Abstract

If the Nuclear Stress Rule of English is ordered within the transformational cycle after all of the syntactic transformations, many apparent exceptions to Chomsky and Halle (1968) are predictable, for the stress patterns of certain syntactically complex constructions reflect those of the simple sentences embedded within them in deep structure. This preservation of basic stress pattern through the syntactic derivation provides a new method for determining underlying grammatical representations and deciding questions of syntax, which is illustrated. The consequences for linguistic theory, in particular the lexical vs. transformational hypotheses (Chomsky to appear), are discussed.

On Sentence Stress and Syntactic Transformations

Joan W. Bresnan
Massachusetts Institute of Technology

Perhaps the fundamental insight of generative phonology is that phonological phenomena are predictable from grammatical representations by a system of ordered rules. These grammatical representations are themselves 'predictable'--that is, generable--given the base and transformational components. In this paper I wish to advance a proposal concerning the interaction of certain phonological and syntactic rules which extends the predictive power of the phonology and at the same time provides a new source of information about syntactic representations. If this proposal is correct it has interesting and far-reaching [illegible] consequences for linguistic theory. The phonological rule to be discussed is the Nuclear Stress Rule (NSR).

The NSR is a cyclic rule applying after all rules affecting the stress of individual lexical items; it is formulated as follows:[1]

$$\text{NSR} \qquad \underset{V}{1} \rightarrow 1 \;/\; [_{A}\; X \;\underset{V}{1}\; Y \;\_\_\; Z \;]$$

where Z may contain no $\underset{V}{1}$ and where A ranges over major categories such as NP, VP, S. Given the convention that any application of 1-stress within a cycle reduces all other stress values by 1, the NSR has the ~~following~~ effect~~s~~ shown in Figure 1.

$[_S$ [Mary] $[_{VP}$ [teaches] [engineering] $_{VP}]$ $_S]$

1	1	1	(word stress)
	2	1	1st cycle: NSR
2	3	1	2nd cycle: NSR

Figure 1

There is a question whether the NSR should be allowed to cycle on VP. Note that if it does not cycle on VP, the stress contour [221] will result in ~~example~~ Figure 1. But there is another rule which alters [221] to [231].[2] Thus, instead of the derivation shown in Figure 1, the type of derivation shown in Figure 2 may be correct:

$[_S$ [Mary] [teaches] [engineering] $_S]$

1	1	1	(word stress)
2	2	1	NSR
	3		[221] → [231]

Figure 2

For the moment I shall ignore this detail in the application of NSR. It is clear that this rule results in primary stress on the rightmost constituent in a sentence. This is, in general, the 'normal' intonation for an English sentence. There are, however, well-known classes of exceptions to this pattern. Final anaphoric pronouns do not normally receive primary stress:

Helen $\overset{1}{\text{teaches}}$ it.
*Helen teaches $\overset{1}{\text{it}}$.

('Normally' means 'excluding emphatic or contrastive stress'.) Nor do final indefinite pronouns receive primary stress normally:

The boy $\overset{1}{\text{bought}}$ some.
*The boy bought $\overset{1}{\text{some}}$.

Other anaphoric items, even when grammatically definite, receive no 1-stress:

John knows a woman who excells at karate,
and he $\overset{1}{\text{avoids}}$ the woman.

In what follows I will assume that by some means or other anaphoric and indefinite elements are not assigned primary stress, and generally I will ignore the stressing of items which are not relevant to the point at issue.

Now the stress patterns of certain syntactically complex constructions appear to violate the general prediction made by the NSR. There are four cases that I will be concerned with here. The first is the type of contrast observed by Newman (1946):

(Ia) George has pl$\overset{1}{a}$ns to leave.
(Ib) George has plans to l$\overset{1}{e}$ave.

Roughly, the meaning of (Ia) is that George has plans which he intends to leave, while (Ib) means that George is planning to leave. The next pair of examples belongs to the same case:

(Ic) Helen left dir$\overset{1}{e}$ctions for George to follow.
(Id) Helen left directions for George to f$\overset{1}{o}$llow.

(Ic) means that Helen left directions which George is supposed to follow, while (Id) means that Helen left directions to the effect that George should follow.

The second case I will consider is quite similar:

(IIa) Mary liked the prop$\overset{1}{o}$sal that George left.
(IIb) Mary liked the proposal that George l$\overset{1}{e}$ave.

Here as in case I there is a syntactic difference corresponding to a difference in stress.

A third case involves questions, direct and indirect:

(IIIa) John asked what Helen had wr$\overset{1}{i}$tten.
(IIIb) John asked what b$\overset{1}{o}$oks Helen had written.
(IIIc) What has Helen wr$\overset{1}{i}$tten?
(IIId) What b$\overset{1}{o}$oks has Helen written?

(IIIe) You can't help noticing how he $\overset{1}{\text{i}}$s.

(IIIf) You can't help noticing how ser$\overset{1}{\text{e}}$ne he is.

(IIIg) Whose have I t$\overset{1}{\text{a}}$ken?

(IIIh) Whose umbr$\overset{1}{\text{e}}$lla have I taken?

It should be noted here that the interrogative *which* is inherently contrastive; in the sentence

Wh$\overset{2}{\text{i}}$ch books has John r$\overset{1}{\text{e}}$ad?

reading is being implicitly contrasted with some other notion:

He has *read* *some* books but only *skimmed* *others*.

That such sentences with *which* do not have the intonation characteristic of case III is therefore of no concern here.

The fourth case involves relative clauses again:

(IVa) George found someone he'd like you to m$\overset{1}{\text{e}}$et.

(IVb) George found some fr$\overset{1}{\text{i}}$ends he'd like you to meet.

(IVc) Let me tell you about something I s$\overset{1}{\text{a}}$w.

(IVd) Let me tell you about something str$\overset{1}{\text{a}}$nge I saw.

The interesting fact about the above apparent exceptions to the NSR is that they are all predictable without any special modifications in that rule, given one assumption: *the Nuclear Stress Rule is ordered after all the syntactic transformations on each transformational cycle*.

Note first that if transformations cycle on the nodes NP and S (Chomsky ~~[illegible]~~ to appear) but not VP, the above assumption entails that NSR applies not on VP within S, but only on NP and S (and any other transformationally cycled nodes). Secondly, the above assumption entails that the NSR is cyclic. I will now verify the above claim.

First I will derive (Ic) and (Id); (Ia) and (Ib) are similar, but involve an additional deletion. The grammatical representations that follow are only approximate. See Figure 3.

$[_S$ Helen left $[_{NP}$ directions $[_S$ for George to follow directions $_S]$ $_{NP}]$ $_S]$

1	1	1	1	1	1	(word stress)
			2	2	1	1st cycle: NSR
					∅	2nd cycle: syntax
2	2	1	3	3		3rd cycle: NSR

Derivation of (1.c)

$[_S$ Helen left $[_{NP}$ directions $[_S$ for George to follow $_S]$ $_{NP}]$ $_S]$

1	1	1	1	1	(word stress)
			2	1	1st cycle: NSR
		2	3	1	2nd cycle: NSR
2	2	3	4	1	3rd cycle: NSR

Derivation of (1.d)

[illegible]

Figure 3

As shown in Figure 3, the stress difference in (Ic) and (Id) is predictable from the fact that in the deep structure of (Ic) *follow* has a direct object, while in (Id) *follow* has no direct object and hence receives primary stress as the rightmost constituent. Case II is parallel: see Figure 4.

```
[S Mary liked [NP the proposal [S that George left the proposal S] NP] S]
    1    1               1              1      1          1                 (word stress)
                               _________2______2__________1________         1st cycle: NSR
              ____________________________________________∅___________      2nd cycle: syntax
____2____2_______________1______________3______3_________________________   3rd cycle: NSR
```

Derivation of (IIa)

```
[S Mary liked [NP the proposal [S that George leave S] NP] S]
    1    1               1              1      1                            (word stress)
                               _________2______1_______                     1st cycle: NSR
              ___________2______________3______1__________                  2nd cycle: NSR
____2____2_______________3______________4______1______________              3rd cycle: NSR
```

Derivation of (IIb)

Figure 4.

In the derivation of case III I have bracketed the examples to reflect the phrase structure rule

$$\bar{S} \ - \ \text{COMP} \ \ S,$$

where $\underset{+\text{WH}}{\text{COMP}}$ is Q, the interrogative morpheme. This rule is justified in Bresnan (to appear). I have omitted the corresponding bracketing from the preceding cases because it plays no role there. I shall derive (IIIa) through (IIId).

[$_S$ John	asked	[$_{\bar{S}}$ COMP +WH	[$_S$ Helen	had	written	something $_S$] $_{\bar{S}}$] $_S$] +wh	
1	1		1		1		(word stress)
			2		1		1st cycle: NSR
		something +wh				∅	2nd cycle: syntax
2	2		3		1		3rd cycle: NSR

Derivation of (IIIa)

Figure 5

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Figure 5
In ~~this example~~ the object of written is the interrogative pronoun what (which I am assuming to be derived from something, though this is not a necessary assumption for the point at issue); pronouns, it should be recalled, do not receive primary stress. Thus the verb retains primary stress.

```
[S John asked [S̄   COMP     [S Helen had written some books S] S̄] S]
                   +WH                           +wh
   1    1                      1          1          1         .    (word stress)
                           ____2__________2__________1_______       1st cycle: NSR
              some books
          ____+wh_____1______________________________ø________      2nd cycle: syntax
______2___2___________1________3__________3_______________________  3rd cycle: NSR
```

Derivation of (IIIb)

Figure 6

As shown in Figure 6, the full NP object of written receives primary stress, causing the stress on written to be lowered. The difference in stress between (IIIa) and (IIIb) reflects the stress difference between the simple sentences embedded in them:

Helen had wr$\overset{1}{\text{i}}$tten something.
Helen had written some b$\overset{1}{\text{o}}$oks.

The same is true of (IIIc) and (IIId): see Figure 7.

Figure [illegible]

```
[S̄   COMP      [S Helen has written something S] S̄]
     +WH                            +wh
                   1           1                    (word stress)
               ____2_______•___1_____ __________    1st cycle: NSR
                                                    2nd cycle: syntax:
 something                        ø                     Question Formation
   +wh
_________has___________ø________________________        Subject-Verb Inversion

                    2     1
         What has Helen written?
```

Derivation of (IIIc)

```
[S̄   COMP      [S Helen has written some books S] S̄]
     +WH                            +wh
                   1           1           1        (word stress)
               ____2___________2___________1____    1st cycle:NSR
                                                    2nd cycle: syntax:
 some books
 +wh   1                          ø                     Question Formation
______________has_________ø_____________________        Subject-Verb Inversion

               1          2     2
          What books has Helen written?
```

Derivation of (IIId)

The analysis given in case III correctly predicts the existence of a stress difference associated with the two readings of sentences like

The parable shows what suffering men can create.

The readings may be indicated as follows:

The parable shows what (suffering men) can $\overset{1}{\text{create}}$.

The parable shows (what $\overset{1}{\text{suffering}}$) men can create.

These examples are exactly analogous to those of case III: the pronominal object what permits the verb to retain primary stress; the full object what suffering causes the verbal stress to be lowered. There are many similar examples, e.g., I forgot how good bread smells.

In cases I and II, the stress difference depended on whether there had been an underlying object of the verb: if so, the verbal stress was lowered; if not, the verb retained primary stress throughout the derivation. In case III the crucial factor was what kind of object the verb had: if pronominal, the verb kept primary stress; if a full object, the verbal stress was lowered. Now in case IV it appears that the kind of object--pronominal or full--affects the stress contours of relatives just as it does questions: see Figure 8.

$[_S$George	found	$[_{NP}$someone	$[_S$he	would	like	you	to	meet	someone $_S]_{NP}]_S]$	
1	1				1			1		(word stress)
					2			1		1st cycle: NSR
									∅	2nd cycle: syntax
2	2				3			1		3rd cycle: NSR

Derivation of (IVa)

$[_S$George	found	$[_{NP}$some	friends	$[_S$he	would	like	you	to	meet	some	friends$_S]_{NP}]_S]$	
1	1		1			1			1		1	(word stress)
						2			2		1	1st cycle: NSR
										∅		2nd cycle: syntax
2	2		1			3			3		- -	3rd cycle: NSR

Derivation of (IVb)

Figure 8

This fact would lead one to predict that the difference between pl$\overset{1}{a}$ns to leave and plans to l$\overset{1}{e}$ave is neutralized when the head is pronominal. In other words, there should be a stress contrast between the relative clause construction of case I--George has pl$\overset{1}{a}$ns to leave--and the same type of construction with a pronominal headHH; this prediction is borne out ~~by the facts~~:

~~Again, this prediction is borne out by the facts~~

George has something to l$\overset{1}{e}$ave.

In general, where the simple sentence embedded in a relative would receive verbal primary stress by itself--

I l$\overset{1}{i}$ke a man (like that),

--the corresponding relative has verbal primary stress:

He's a man I l$\overset{1}{i}$ke.

In these two examples a man is predicative. If a man is specific, it can receive primary stress in the simple sentence:

I like a (certain) m$\overset{1}{a}$n.

And correspondingly we find

A (certain) m$\overset{1}{a}$n I like...

There are sentences in which just this stress difference decides the reading; for example

A man I like believes ~~approves~~ in ~~of~~ women's liberation.

When man has greater stress than like, the sentence is understood as being about a certain man; when like carries greater stress than man, the sentence is, in a sense, about the speaker.[3]

All of the cases discussed involve the movement or deletion of verbal objects rather than subjects. The reason is that since the NSR assigns primary stress to the rightmost element, only cases in which the underlying rightmost element has been affected by transformations can provide crucial evidence. Thus both the ordering hypothesis advanced here and the previously proposed ordering can account for the stress in

I asked whose children bit F$\overset{1}{i}$do,

the man whose children bit my d$\overset{1}{o}$g

a desire to $\overset{1}{e}$at

But only the new ordering hypothesis accounts for the stress in

I asked whose ch$\overset{1}{i}$ldren Fido bit,

the man whose ch$\overset{1}{i}$ldren my dog bit

f$\overset{1}{o}$od to eat

In the latter examples the underlying objects have diverged from their original rightmost position, where they had caused the verbal stress to be lowered during cyclic application of the NSR.

The ordering hypothesis expresses the fact that the stress patterns of certain syntactically complex constructions reflect those of the simple sentences embedded within them in deep structure. This preservation of basic stress pattern through the syntactic derivation provides a new method for determining underlying grammatical representations and deciding questions of syntax. To illustrate this method, I will consider the following question. It has been proposed (most recently by Emonds (1970) but earlier by Lees (1960)) that certain infinitival complements should be derived from deep structure VP's rather than S's. Suppose this proposal is applied to the analysis of certain adjective + complement constructions. The question is whether in a construction like

It is ~~hard~~ tough for students to solve this problem,

there is an underlying S = [for students to solve this problem] or an underlying PP + VP = [for students][to solve this problem].[4]

There are several facts which argue against the sentential analysis: first, if there were an underlying sentence, one would normally expect such a sentence-cyclic transformation as *There* Insertion to take place. 42 = ⑤ But though one can say

It will be ~~hard~~ tough for at least some students to be in class on time,

one cannot say

*It will be ~~hard~~ tough for there to be at least some students in class on time.

Compare cases which are truly sentential:

The administration is eager for there to be at least some students in class on time.

The commander left directions for there to be a soldier on duty at all times.

It wouldn't surprize me for there to be countless revolutionaries among the secretaries.

Second, the for complementizer of a true sentential complement allows many types of objects which the preposition for after hard does not:

Emmy was eager for that theorem on modules to become known.

*It was tough for that theorem on modules to become known.

It would surprise me for a book on Hittite to please John.

*It would be tough for a book on Hittite to please John.

Third, the complement of hard, tough, a bear, a breeze, and similar predicates does not behave as a sentential constituent under S Movement: compare a true sentential complement--

It is surprising [for a women to act that way $_S$]

[For a women to act that way $_S$] is surprizing

--with the complement of hard or tough:

It is hard for a woman to act that way.

*For a woman to act that way is hard.

It's tough for students to grasp this concept.

*For students to grasp this concept is tough.

It is a difficult syntactic problem to determine the correct analysis of for constructions. The above ordering hypothesis provides new evidence bearing on this problem for hard and the other adjectives of this construction are subject to a transformation which affects the object of the complement to produce such sentences as

This theorem was a breeze for Emmy to prove.

Given that transformations do not cycle on VP, the hypothesis advanced above results in exactly the right stress contours for these sentences if the complement is represented as PP + VP. To illustrate, suppose that the figure 9 shows a permissible deep structure for that theorem was tough to prove ignoring details:

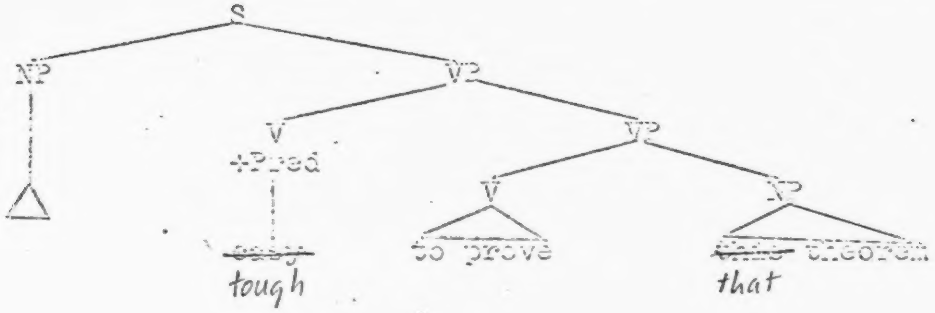
S
NP
VP
V
+Pred
~~easy~~
tough
VP
V
to prove
NP
~~this~~ theorem
that

Figure 9

As noted there is no cycle on VP, so not until S will any rules apply. At that point the object of prove is shifted, yielding the derived structure shown in figure 10.

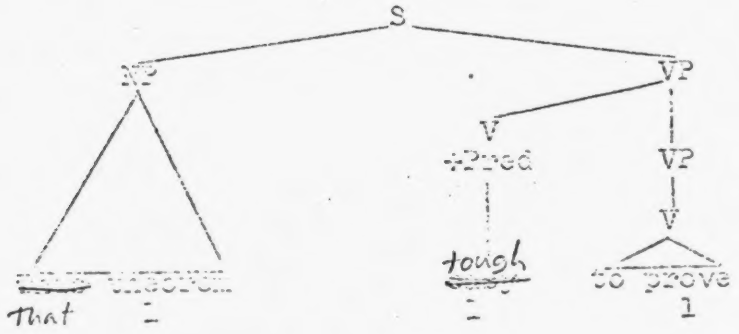
S
NP
VP
V
+Pred
VP
V
~~this~~ theorem
That
1
tough
~~easy~~
1
to prove
1

Figure 13

Then NSR will apply, giving the contour [221], which will eventually become [231] by the rule referred to in note 2.

On the other hand, suppose this example came from a deep structure with a sentential complement to *tough*, for example: that shown in Figure 11.

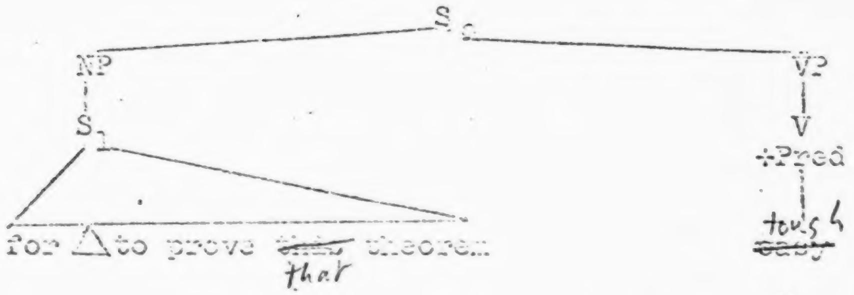
S0
NP
VP
S1
V
+Pred
for △ to prove ~~this~~ that theorem
~~easy~~ tough

Figure 11

Again, the exact details of the representation are immaterial. The NSR would apply on the S_1 cycle, producing *$\overset{2}{\text{prove}}$ ~~this~~ that $\overset{1}{\text{theorem}}$*; on the S_0 cycle *~~this~~ that $\overset{1}{\text{theorem}}$* would be moved into subject position and S_1 extraposed: see Figure 12.

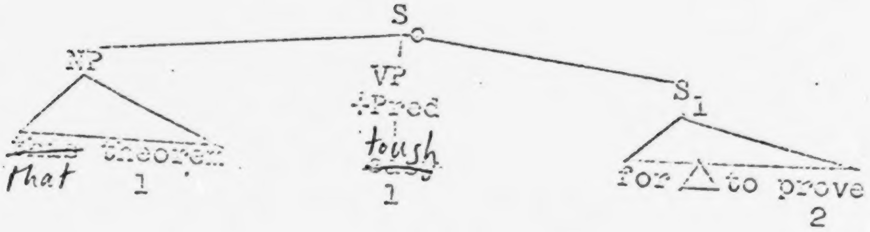
S
o
NP
VP
+Pred
~~easy~~ tough
1
S
1
~~This~~ That theorem
1
for △ to prove
2

Figure 12

again NSR would apply, yielding the incorrect contour *[213].[6=⑦]

In this way one is led to conclude from both stress and syntax that VP as well as S must be a possible adjectival complement in deep structure. (See Appendix I for further discussion.) A given adjective may therefore be subcategorized for VP or S (or both). If the Object Shift transformation applies only to adjectives with VP complements, there will be no need to resort to rule features to describe this phenomenon; that is, arbitrariness in the grammar may be reduced by stating object shift in such a way that it will apply only to VP complements.[8]

There is in fact a class of adjectives permitting both S and PP + VP complements, namely, the class including _good_, _bad_, _smart_, _pleasant_, and _appropriate_. The ambiguity in such cases was noticed by Lees (1960). The sentence

It is good for John to leave,

may mean either

For John to leave is good.

= It is good (for John to leave)

or

To leave is good for John.

= It is good for John (to leave)

Less maintains a clear distinction between the ambiguous class (good; his type 7) and the unambiguous class (*hard*; *tough* his type 8), but some speakers may class certain of the latter with the former, permitting sentences like[9]

(hard)
( )
For John to please Mary is (easy)
( )
(difficult)

The possibility of both VP and S complements for these adjectives accounts for the following paradigm:

(good)
(Xa) *Such things are not ( ) for there
(appropriate)
to be children involved in.

(good)
(Xb) It is not ( ) for there to be
(appropriate)
children involved in such things.

(good)
(Xc) Such things are not ( ) for children
(appropriate)
to be involved in.

(good)
(Xd) It is not ( ) for children to be
(appropriate)
involded in such things.

The fact that (Xa) is ungrammatical is precisely what is predicted from the analysis given there. For *good* and *appropriate* may take both S and VP complements. Object

Shift can apply only to VP complements, as shown in n.8, and *There* Insertion can apply only to S complements. The presence of *there* is (Xa) and (Xb) forces the 'S interpretation' of the complement in both (Xa) and (Xb) and hence the shifted object in (Xa) is ungrammatical.[10]

I have discussed adjectives which, like tough, take only (PP) + VP complements as well as adjectives which, like *good*, take both (PP) + VP and S. It should not be surprising to discover adjectives taking (PP) + S, and indeed that is just what we would expect if VP is, with S, a possible complement generated in phrase structure: the phrase structure rules will specify VP as an alternative choice wherever S is specified, as in the rule

$$VP \longrightarrow \ldots\ (PP)\ \left(\begin{Bmatrix} VP \\ S \end{Bmatrix}\right)$$

One adjective which displays the possibility PP + S is *good*:

For Mary to learn karate would be good for her.

It would be good for Mary for her to learn karate.

In fact, one would predict that Object Shift cannot apply to these examples, since a full S follows *for Mary*, and this prediction is borne out:

*Karate would be good [for Mary$_{PP}$] [for her to learn$_{S}$]

Karate would be good [for Mary$_{PP}$] [to learn$_{VP}$]

The ungrammaticality of **Karate would be good for Mary for her to learn* is another crucial test in favor of the formulation of Object Shift given here.

To conclude, it is because both the *easy to please* and the passive construction have rightward primary stress that I have ordered the NSR after all transformations on each cycle. This ordering guarantees that on a given cycle Object Shift or Passive may apply before the NSR:

John was seen by $\overset{1}{\text{Mary}}$.

John was hard to $\overset{1}{\text{see}}$.

Note that the same applies to Noun Phrases: the passivization of nominals (Chomsky to appear) also precedes the NSR:

the enemy's destruction of the $\overset{1}{\text{city}}$

the city's destruction by the $\overset{1}{\text{enemy}}$

On the other hand, within a derivation Question Formation and Relative Clause Formation must apply after the NSR has affected the simple S's embedded in interrogative and relative structures:

What $\overset{1}{\text{books}}$ has Helen written?

I wonder what $\overset{1}{\text{books}}$ Helen has written.

Here's a $\overset{1}{\text{book}}$ for you to read.

This ordering follows automatically from the principle of the transformational cycle and the analysis of syntactic structures given, in which there is a simple S embedded within interrogatives as well as relatives (Bresnan to appear). That Question Formation and Relative Clause Formation actually do apply on the transformational cycle is shown in Appendix II by independent syntactic arguments.

Some Consequences

The ordering of the NSR proposed here has interesting consequences for linguistic theory. The most immediate consequence is, of course, the inadequacy of a basic assumption of generative phonology (Chomsky and Halle:15):

It is well known that English has complex prosodic contours involving many levels of stress... It is clear even from a superficial examination that these contours are determined in some manner by the surface structure of the utterance.

Instead it appears that the stress contours of English sentences are determined in a simple and regular way by their underlying syntactic structures. Further, because prosodic stress rules like the NSR require prior assignment of word stress, the latter must occur either on deep structure or in the lexicon.[11] But if word stress is assigned prior to the syntactic transformations, then it follows automatically that ~~[illegible]~~ transformationally attached affixes are stress-neutral.[12] For example, the primary stress on the verb *derive* is unchanged by the affix *ing* but shifts when *ation* is affixed:

      1
    deriving
        1
    derivation

This would follow if *ing*, but not *ation*, were attached to *derive* by a syntactic transformation. But this is exactly what Chomsky (to appear) argues on independent syntactic and semantic grounds: his lexicalist hypothesis states that gerundive nominals like

Wanda's deriving the answer

--which are productive and sentence-like--are created by syntactic transformation, while derived nominals like

Wanda's derivation of the answer

--which are restricted and noun-like--are created by lexical rules. Because the NSR may apply on the first syntactic cycle, and because word-stress assignment precedes prosodic stress assignment, all lexical insertion must occur on or before the first transformational cycle. If there is some level in derivations at which all lexical insertion converges, then deep structure, in the sense of Chomsky (1965) exists. Now the assignment of word stress prior to prosodic stress simply follows from the principle of the phonological cycle (Chomsky and Halle 1968): in other words, the stress of the whole is a function of the stress of the parts. Therefore, *it is a consequence of the ordering hypothesis presented here together with the principle of the phonological cycle that the lexical hypothesis (Chomsky to appear) is correct and that deep structure exists*.

Those grammarians who accept the transformational hypothesis (see Chomsky (to appear) for references) must either reject the stress ordering hypothesis presented here or the principle of the phonological cycle. Let us see what is entailed in the latter course. One concrete way of rejecting the phonological cycle is to claim that the NSR assigns stress to nonterminal symbols only and that word stress occurs subsequently.[13] This proposal implies that prosodic stress does not depend in any way on lexical information, but only on syntactic configurations. Yet, as we have seen, the NSR must 'know' whether it is applying to a pronoun or to a fully specified lexical noun phrase in order for the systematic difference between such pairs of examples as these to be explained:

Helen detests mis$\overset{1}{o}$gynists.

Helen det$\overset{1}{e}$sts them.

The parable shows (what s$\overset{1}{u}$ffering) men can create.

The parable shows what (suffering men) can cre$\overset{1}{a}$te.

(Because the ordering hypothesis entails that pronouns are in deep structure, it is interesting to observe that recent work has shown independently that they are present in deep structure and not created transformationally: see, for example, Jackendoff (1969), Dougherty (1969), and Bresnan (1970).) The same is true of semi-pronouns like people, things:

I $\overset{1}{\text{like}}$ people.

There are many people I $\overset{1}{\text{like}}$.

Similarly, the derived stress contours of sentences containing anaphoric and nonanaphoric noun phrases differ:

$\overset{2}{\text{John}}$ $\overset{3}{\text{knows}}$ a $\overset{1}{\text{woman}}$.

$\overset{2}{\text{John}}$ $\overset{1}{\text{avoids}}$ the $\overset{3}{\text{woman}}$.

Different stress contours are produced by the NSR as a function of the difference in stress between anaphoric and nonanaphoric lexical items. It is hard to see how this dependency of stress contour on the stress level of individual lexical items can be explained if the phonological cycle, is given up.

Another interesting consequence of the ordering hypothesis is this: English is not a VSO (Verb Subject Object) language in the sense of McCawley (1970).[14] The reason is just this: McCawley proposes that English has underlying VSO word order throughout the transformational cycle and converts to SVO (Subject Verb Object) only by a postcyclic verb-~~subject-inversion~~ second rule. In McCawley's system intransitive verbs would precede their subjects throughout the cycle, and thus get reduced stress by the cyclic application of the NSR. Instead of

$\overset{2}{\text{Jesus}}$ $\overset{1}{\text{wept}}$.

the incorrect contour

*$\overset{1}{\text{Jesus}}$ $\overset{2}{\text{wept}}$.

would result as the normal English intonation. On the other hand, if McCawley's verb-second rule were cyclic, his arguments for underlying VSO order in English would disappear.

We see that the stress ordering hypothesis provides a kind of 'naturalness condition' on syntactic derivations: the formal properties of surface structures cannot diverge too greatly from those of deep structures without destroying the relation between syntax and prosodic stress. In a sense, it is natural that a close relation should exist between sound and syntactic structure; after all, languages, unlike the countless logics and 'logical languages' invented by philosophers, are spoken. It is not surprising that McCawley's system, explicitly modelled on one kind of notation used in symbolic logic, proves to be an inadequate syntactic basis for a description of English stress contours.

Having sketched these consequences for linguistic theory, I would finally like to consider three problems for further research.

The first problem concerns sentences like

> This theory was believed by George to have
> been thought by Paul to have been refuted
> by Jim.

It is possible that such sentences derive from an underlying form close to

> $[_S$ George believed $[_S$ that Paul thought
> $[_S$ that Jim refuted this theory $_S]$ $_S]$ $_S]$

by a sequence of operations indicated in Figure 13 note the derived stress contours.

```
[George believed [Paul thought [Jim refuted this theory]]]
   1        1       1     1       1     1           1      (word stress)
                               this theory was refuted by J.   Passive
                                       1           1       1
                                       2           2       1   NSR
                               -----------------------------
                  Paul thought this theory [∅ to have been refuted by J.]   Subject Raising
                    1     1           2                       2       1

                this theory was thought by P. to have been refuted by J.    Passive
                       2          1        2                  2       1
                       3          2        2                  3       1     NSR
                --------------------------------------------------------
George believed this theory [∅ to have been thought by P. to have been refuted by J.]  Subject
  1        1           3                      2        2                  3       1    Raising
this theory was believed by G. to have been thought by P. to have been refuted by J.   Passive
       3           1        1                 2        2                  3       1
       4           2        2                 3        3                  4       1    NSR
---------------------------------------------------------------------------------------------
```

Figure 13

Evidently, these syntactic processes can be repeated indefinitely:

> This theory was expected by Dave to have
> been believed by George to have been
> thought by Paul to have been refuted by Jim.
> This theory was said by Haj to have been
> expected by Dave to have been believed by
> George to have been thought by Paul to have
> been refuted by Jim.

In such a way the derived subject this theory may receive stress indefinitely weak compared to the verb. This result is clearly wrong. Therefore, if the syntactic derivation of such sentences is correct, it appears that some convention limiting iterated stress reduction is needed. Just this conclusion is argued independently in Bierwisch (1968). Further research on the form and scope of the stress reduction convention is necessary; if stress reduction is limited, the observed variation can be effected by 'rhythm' rules, e.g. [2221] - [2321].

A second problem may lie in the formulation of the Nuclear Stress Rule itself. The problem is seen when there is more material than one Noun Phrase to the right of the verb. Compare these examples:

> Peter used a $\overset{1}{\text{knife}}$.
>
> Whose $\overset{1}{\text{knife}}$ did Peter use?

Peter sliced the salami with a kn$\overset{1}{\text{i}}$fe.

Whose knife did Peter slice the sal$\overset{1}{\text{a}}$mi with?

The first pair, but not the second, is explicable from what I have proposed so far. Here are further examples like the second pair:

Mary found a car on Thursday $\overset{1}{\text{e}}$vening.

On what evening did Mary find a c$\overset{1}{\text{a}}$r?

Mary gave a book to Peter's ch$\overset{1}{\text{i}}$ldren.

Whose children did Mary give a b$\overset{1}{\text{o}}$ok to?

What book did Mary give Peter's ch$\overset{1}{\text{i}}$ldren?

Recall that the effect of the NSR is to lower stress on every element to the left of the rightmost primary stress within the appropriate contexts. The above examples suggest that perhaps all primary-stressed items to the right of the verb--and not just the rightmost--should retain primary stress until the late application of a rhythm rule. This conjecture is illustrated in Figure 14.

```
[S Peter sliced the salami with a knife ]
    1     1         1          1      (word stress)
    2     2         1          1       revised NSR
 ______________________________
    2     3         2          1       rhythm rule


[S   COMP   [S Peter sliced the salami with someone's knife ] ]
     ± WH                                   +wh
               1     1         1                   1      (word stress)
               2     2         1                   1      revised NSR
            ____________________________________________
someone's knife                             ∅      ∅      Question Formation
 ±wh
               did Peter slice                            Subject-Verb Inversion
 whose knife did Peter slice the salami with
       1        2     2         1
       2        3     3         1                         revised NSR
 ______________________________________________________
```

Figure 14

The third problem[16] is to account for the following contrast:

(A) The Jones made plans for $\overset{1}{\text{dinner}}$.

(B) The Jones made $\overset{1}{\text{clams}}$ for dinner.

As it stands, *plans for $\overset{1}{\text{dinner}}$* is the predicted stress contour; the problem lies with (B). Note that when a pronoun is used for *clams*, the stress shifts rightward:

The Jones made them for $\overset{1}{\text{dinner}}$.

Further, *plans for dinner* but not *clams for dinner* is a constituent:

Plans for dinner were made by the Jones.

*Clams for dinner were made by the Jones.

It appears that the formulation of the NSR may have to take into account certain kinds of prepositional phrases.

Although the problem posed by (B) is still unsolved, the basic principle that stress patterns are preserved through syntactic derivation still holds: compare (A) and (B) with (C) and (D):

(C) The plans we made for $\overset{2}{\text{dinner}}$ didn't come $\overset{1}{\text{off}}$.

(D) The $\overset{2}{\text{clams}}$ we made for dinner didn't come $\overset{1}{\text{off}}$.

Therefore, as in the preceding cases, this problem concerns the proper formulation of the NSR rather than the ordering hypothesis: once the principle for applying stress to (B) is found, the ordering hypothesis will predict (D).

Appendix I

The existence of VP complements in deep structure is not a necessary consequence of the ordering hypothesis presented here. It is possible to 'preserve sentences', so to speak, by deriving John is ~~easy~~ tough to please from

John$_i$ is ~~easy~~ tough [$_S$ ...to please him$_i$]

The presence of the pronominal object of please will allow the verb to retain primary stress on the innermost S-cycle and the presence of a specified subject John would prohibit a sentential subject: *For Mary to please John is ~~easy~~. However, this solution leaves unexplained several of the other nonsentential properties of such constructions:

(1) the absence of There Insertion
(2) the selectional properties of for
(3) the generalization that ~~o~~Object ~~s~~Shift does not cross S-brackets

Further, it would require some sort of special constraint to guarantee the presence of a pronominal object in the complement which would have the subject of ~~easy~~ tough as antecedent.

NB -- unified case -- all other bound anaphora involves part-whole, species of theory, etc

It is possible to amend the above solution to take account of (1)-(3), though the proposed amendment is ad hoc. Suppose that Mary is ~~easy~~ for John to please were derived from

(Y) Mary$_i$ is tough $[_{PP}$ for John$_j]$$[_S$ he$_j$ please her$_i]$ by two obligatory deletions--Object Deletion, affecting *her*$_i$, and Equi-NP Deletion, affecting *he*$_j$. See Postal (1968a) on the latter transformation. Object Deletion will be written almost exactly as Object Shift is stated is n.8:

$$[_S \underset{1}{\text{NP}}\ \underset{2}{\text{Pred}}\ \underset{3}{\text{(PP)}}[\underset{4}{\text{V*}}\ \underset{5}{\text{NP}}]_{VP}]-1\ 2\ 3\ 4\ \emptyset$$

The PP in (Y) would account for (2); a new constraint that the subject of the complement take the object of the preposition as antecedent will take care of (1), since *there* cannot be an underlying subject and cannot replace anaphoric pronouns; and (3) will follow from the pruning of the embedded S after Equi-NP Deletion. This solution requires, of course, that Equi-NP Deletion be cyclic (contra Postal 1968a) in order to derive *Mary is believed by everyone to be tough for John to please*, Object Deletion must take place before the cyclic passive rule; and Equi-NP Deletion must precede Object Deletion so that S will prune to VP.

It is quite striking that this method of preserving a sentential complement for adjectives like *easy* uses only the bare verbal skeleton of the sentence: subject and object are obligatorily deleted pronouns, so that the postulated underlying S has no trace in any surface form derived from the proposed deep structure (Y).

Appendix II

I have shown that it is possible for the NSR to be ordered within the transformational cycle, but I have not actually shown that it is necessary. For I have assumed without explicit justification that Relative Clause Formation and Question Formation are cyclic transformations. If these transformations were not cyclic one might think of ordering the NSR after the entire transformational cycle but before the postcyclic transformations, taking the latter to include Relative Clause Formation and Question Formation.[17] There are two kinds of evidence against this alternative. First, all of the stress evidence indicates that the NSR does not precede known postcyclic transformations; for example, we do not have

    1   2
    *Away ran Fido.

but rather

    2   1
    Away ran Fido.

The former would result if the NSR preceded the postcyclic transformation which preposes _away_. Likewise, we do not have

    1   2   3
    *Seldom does John sing.

but rather

    2   3   1
    Seldom does John sing.

~~(See Emonds (1970) on both of these transformations~~

Yet the former would result if the NSR preceded the postcyclic transformation which fronts _seldom_.[18] (See Emonds (1970) on both of these transformations, Directional Adverb Preposing and Negative Adverb Preposing.)

Second, there is syntactic evidence that Relative Clause Formation and Question Formation are indeed cyclic transformations. Because of the consequences for linguistic theory of the cyclicity of the NSR, I will demonstrate here that Question Formation (QF) and Relative Clause Formation (RCF) are cyclic transformations. The matter is of some intrinsic interest as well.[19] From this demonstration and the fact that the NSR precedes these transformations while following other cyclic transformations, it can be concluded that the NSR is indeed cyclic, applying after all the transformations applying to each cycle.

As preparation, observe that there is a transformation which performs operations like the following:

Mary has studied little and yet Mary has accomplished a great deal. --->

Mary has studied little and yet accomplished a great deal.

This transformation, which I will refer to as Right Conjunct Reduction, may be thought of as deleting material in the right conjunct which repeats that in the left.[20] The conjuncts may be full sentences, as above, or noun phrases:

The trees in Northern California and the trees in Oregon are similar. --->

The trees in Northern California and (in) Oregon are similar.

The argument I will give consists in showing that there are derivations in which Right Conjunct Reduction may follow an application of QF and derivations in which it may precede an application of QF. To show the latter it will be necessary to use a transformation which I shall call Postposing. This is an optional rule which postposes certain complements to noun phrases, relating pairs like these:

The news from Italy was the same. →
The news was the same from Italy.

The results on the virus were parallel. →
The results were parallel on the virus.

The stories about her are similar. →
The stories are similar about her.

Such a transformation is needed to explain certain peculiarities in the distribution of prepositional phrases. For example, the impossibility of

*That was the same from Italy.

is explained by the ungrammaticality of its source under Postposing:

*That from Italy was the same.

Prepositional phrases which can be generated to the right of predicates are not excluded by such pronominal subjects:

That is the same in France.
They were similar during the occupation.

Postposing preserves structure (Emonds 1970), so that if a prepositional phrase already occupies immediate post-predicate position, the rule does not apply (i.e. since a node is moved by a structure preserving rule only into a place where the same node can be generated by the base, the transformation does not apply if the place is already filled):

Some things about France are quite similar to those you mention about England.

*Some things are quite similar to those you mention about England about France.

*Some things are quite similar about France to those you mention about England.

Cf. Some things are quite similar about France.

(The last sentence should be imagined in a conversational context, e.g. *Concerning what you have just observed about England, I can add that some things are quite similar about France*.)

Their results on that virus were parallel to ours on the phage.

*Their results were parallel to ours on the phage on that virus.

*Their results were parallel on that virus to ours on the phage.

A second useful fact about Postposing may be inferred using

55

the fact that it is structure preserving. We have seen that the sentence

Their results on that virus are similar to our results on the phage.

cannot undergo Postposing, because there is already a prepositional phrase in immediate post-predicate position:

*Their results are similar to our results on the phage on that virus.

Now suppose that the post-predicate phrase is removed by QF:

To whose results on the phage are their results on that virus similar?

If it were in general possible for Postposing to follow QF, then these ungrammatical strings would result:

*To whose results are their results on that virus similar on the phage?

*To whose results on the phage are their results similar on that virus?

The conclusion is that Postposing precedes QF on any cycle.

A final fact needed for the ensuing argument is that Right Conjunct Reduction precedes Postposing on any cycle. Consider the following derivations, in which Right Conjunct Reduction precedes Postposing:

The facts about him and the facts about her were virtually identical, but he got the job. →

The facts about him and (about) her were virtually identical, but he got the job. →

The facts were virtually identical about him and (about) her, but he got the job.

The wines from the eastern regions of France and the wines from the western regions of Germany are quite similar. →

The wines from the eastern regions of France and (from) the western regions of Germany are quite similar. →

The wines are quite similar from the eastern regions of France and (from) the western regions of Germany.

For Postposing to precede Right Conjunct Reduction in such cases, there would have to be a step like this in the derivation:

The facts about him and the facts about her were virtually identical, but he got the job. →

*The facts and the facts were virtually identical about him and (about) her, but he got the job.

As shown, Postposing would have to separate the prepositional phrases from their conjoined subjects; but this operation is in general impossible:

The rumors about Adele and the gossip concerning Jean were similar. →

*The rumors and the gossip were similar about Adele and concerning Jean.

Therefore, taking the second and third facts together, we have this ordering on any cycle:

Right Conjunct Reduction

Postposing

Question Formation (QF)

~~But~~ note that there are two situations that may arise in deep structure. There may be a single interrogative S containing conjoined nodes embedded within it, or there may be two interrogative S's contained within a conjoined structure. In the latter case we would expect Right Conjunct Reduction to follow QF, if QF were cyclic, and this is just what happens. To proceed with the argument, note that Right Conjunct Reduction must apply after QF in this derivation:

(a) I wonder what strange sights yòu'll see in mý country and what strange sights Ì'll see in yóur country. →

(b) I wonder what strange sights yòu'll see in mý country and Ì'll see in yóur country.

QF has already applied to (a). If Right Conjunct Reduction only preceded QF in derivations, (b) would not be generable. For to apply prior to QF, Right Conjunct Reduction would have to delete the material between the verb and prepositional phrase which has not yet been fronted by QF: but this operation is in general impossible, producing ungrammatical strings:

*You'll hit some great spots in my country and I'll hit in your country.

Conjunct Reduction may only delete repeated material at the extreme of the conjunct. This establishes that Right Conjunct Reduction must follow QF to derive (b).

On the other hand, Conjunct Reduction must also be able to precede QF within a derivation. Consider the following assertion and question:

(y) He said that some things about France and some things about Italy were similar.

(z) What things did he say were similar about France and (about) Italy?

(z) cannot be taken as a base form for the same reasons that show Postposing to be a transformation. For example, this sentence certainly has no reading like (y)'s:

*He said that they are similar about France and (about) Italy.

Therefore, (z) must have an application of Postposing in its derivation. Now we already know that Postposing cannot follow QF, so it must precede QF in the derivation of (z). Right Conjunct Reduction must in turn precede Postposing in the derivation of (z), for otherwise Postposing would have to detach prepositional phrases from conjoined subjects, an operation which has been shown to be impossible:

He said that what things about France and what things about Italy were similar? →

*He said that what things and what things were similar about France and about Italy?

But this means that Right Conjunct Reduction must precede QF in the derivation of (z):

He said that what things about France and what things about Italy were similar? →

He said that what things about France and (about) Italy were similar? →

He said that what things were similar about France and (about) Italy? →

What things did he say were similar about France and (about) Italy?

We see that both sentence (z) and the sentence

What things about France and (about) Italy did he say were similar?

are derived by applying Right Conjunct Reduction and then QF; the only difference is that in (z) the optional Postposing rule intervenes after Right Conjunct Reduction and before QF. We used Postposing merely as a means of 'forcing' Right Conjunct Reduction to apply before QF in this derivation.

From the demonstration that there is a derivation in which Right Conjunct Reduction must precede and a derivation in which it must follow QF, I conclude that both are cyclic transformations.

Let us turn now to Relative Clause Formation (RCF). We see at once that an argument exactly parallel to the last can be formulated using a sentence analogous to (z) to show that Conjunct Reduction can precede RCF--

The things that he said were quite similar about France and (about) Italy were these.

--and a sentence analogous to (b) to show that Conjunct Reduction may follow RCF--

There are many strange sights that yòu'll see in mý countrý and (that) Ì'll see in yóur country.

RCF is not only cyclic, it is NP-cyclic. That is, its domain of application is NP rather than S, just as I have assumed in the stress derivations. This formulation is syntactically necessary to derive ~~X~~ 'double relatives', such as

The men she has met that she likes are all artists.

The only solution I've found that satisfies me is this. Each example contains two relatives but only one head. For the first there would be an underlying representation (roughly) like that shown in Figure 15. (I make no stand here on whether relatives come from the Determiner in deep structure; if so, then the transformation which shifts them to the right of the head must be NP-cyclic to produce the configuration in Figure 15.) If RCF applies to NP, the derivation is easily accomplished by first applying RCF to NP_1 and then NP. Otherwise the sentence cannot be derived without letting cyclic transformations reapply on the same cycle.

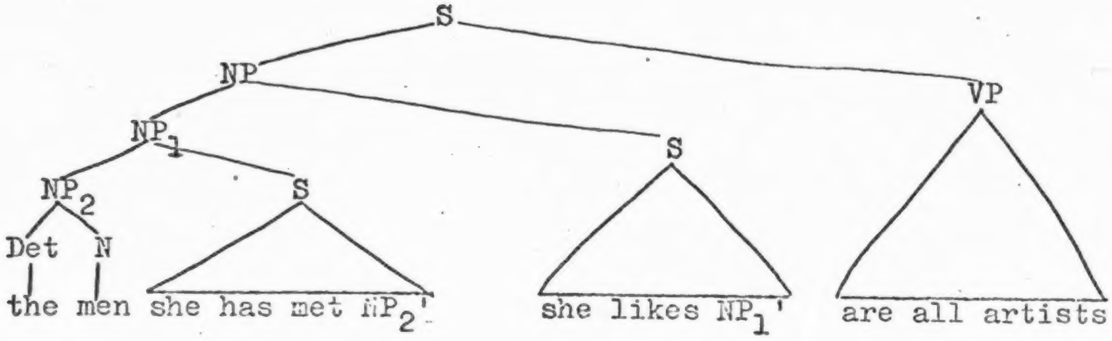
S
NP
VP
NP_1
S
NP_2
S
Det
N
the men she has met NP_2'
she likes NP_1'
are all artists

Figure 1~~3~~5

Notes

[1] This is the preliminary formulation given by Chomsky and Halle (1968:17), though later they collapse the NSR with another rule. If the proposal of this paper is correct, the NSR should remain as first formulated. The statement of the rule in Chomsky and Halle (1968) omits the condition on Z which guarantees that only the rightmost primary-stressed vowel receives 1-stress by the NSR.

[2] This rule is tentatively stated in Chomsky and Halle (1968:115-117) as a word-stress rule; they note that it could be generalized to such cases as I am considering here. I am assuming that the NSR may apply to any phrase node, including VP, in isolation.

[3] Under the latter reading the sentence is generic, and may be paraphrased (approximately) as

A [=any] man I like $\left\{\begin{matrix}\text{must}\\ \text{would}\end{matrix}\right\}$ believe...

Some examples of the general types I have been discussing are given in Bolinger (1968) as counterexamples to the observations in Newman (1946). As I have shown, these are only apparent counterexamples to the theory of generative phonology. A very few of Bolinger's examples--mostly idiomatic, e.g. *money to búrn*--remain unexplained.

[4] This is not an exhaustive alternative in that, if VP and S are both available as underlying complements, one would expect a full range of possible subcategorizations

for Adjectives: VP, S, PP + VP, PP + S, etc. These possibilities are compactly expressed in the rule

$$VP \rightarrow \ldots (PP) \left(\begin{Bmatrix} VP \\ S \end{Bmatrix} \right).$$

In fact, as will become clear, all of these possibilities are realized with various adjectives. But there do exist predicates which clearly resist S complements, including PP + S complements:

*For John to accept this view would be tough (for him).

*It would be tough for John for him to accept this view.

*For us to solve that problem was a bear (for us).

*It was a bear for us for us to solve that problem.

Cf. That problem was a bear for us to solve.

In Appendix ~~th~~ I the possibility of 'preserving' an S analysis for *tough*, *a bear*, and other predicates by deriving their PP + VP complements from PP + S is discussed.

Note that it is immaterial here whether the complement is conceived as originating in subject position or at the rightmost position in VP. See Emonds (1970) for a general argument in favor of the latter view.

5 *There* Insertion places the expletive *there* is subject position before certain indefinites:

There will be a son of the nobility present.

There Insertion is cyclic, since it may both follow and precede Passive in a derivation. It follows Passive in this derivation:

While you watch, a pig will be roasted. →

While you watch, there will be a pig roasted.

(The latter sentence must be carefully distinguished from:

?While you watch, there will be a roasted pig.

?While you watch, there will be a pig that is roasted.

In these examples, Passive has not applied to the main sentence.)

There Insertion precedes Passive in this derivation:

△ proved that mercury was in the bottle. →

△ proved that there was mercury in the bottle. →

There was proved to be mercury in the bottle.

6 The problem lies in determining the correct criteria to distinguish among the many possible analyses. The S Movement criterion is probably the best type for determining simple sentencehood.

7 The connection between this type of construction and the ordering hypothesis advanced here was brought to my attention by Joan Maling.

8 Object Shift may be (tentatively) stated as follows:

$$[_{S}\ \triangle\ \text{Pred (PP)}\ [_{VP}\ V^{*}\ (P)\ NP\ ]]$$

where V* represents an arbitrarily long string of Verbs. This formulation would permit derivation of

John is easy for Bill to please.

John is hard for Bill to even try to please.

John is hard for Bill to even begin to try to please.

but not

*You are tough for me to believe that Harry hates.

(Postal 1968:103)

> *Harriet is tough for me to stop Bill's
> looking at. (Postal 1968:109)

Postal (1968:102) states that Object Shift (his 'Tough Movement') transports an NP into subject position only from an 'immediately lower clause'. This statement leads him to both awkward complications of the rule and ad hoc theoretical elaborations. While Postal's version states that Object Shift may not occur across *more than one* S-bracket, the version of the rule given here states, in effect, that Object Shift may not occur across *any* S-brackets. There is therefore an empirical difference between these two versions, and the crucial evidence is presented in paradigm (X) of this paper. The evidence there, as the reader will note, crucially favors an 'intrasentence' version of the rule over any 'cross-sentence' version; that is, any version like Postal's will incorrectly predict that (Xa) is a grammatical sentence.

[9] One such speaker is Postal (1968:25) who writes:

one must observe that the whole construction involves a subtle structural ambiguity of a not understood type. A string like:

3.(8) It was difficult for Tony to rob the store

has two different Surface Structures:

3.(9) a it was difficult for Tony (to rob the store)

b it was difficult (for Tony to rob the store)

The difference in meaning is real though subtle. The first seems to associate the difficulty directly with Tony personally. The second allows for a more generic attribution of difficulty. The difference shows up clearly in two variant pronunciations.

The sentence *John was good to leave* is itself ambiguous: John may be understood as the one leaving (*It was good of John to leave*) or the one left (*It was good to leave John*). Corresponding to these readings is a differnce in stress:

J$\overset{3}{o}$hn was g$\overset{2}{o}$od to le$\overset{1}{a}$ve (John is subject of *leave*)

J$\overset{2}{o}$hn was g$\overset{3}{o}$od to le$\overset{1}{a}$ve (John is object of *leave*)

The former is probably transformationally derived from

It was g$\overset{2}{o}$od of J$\overset{3}{o}$hn to le$\overset{1}{a}$ve.

Of John is probably a PP complement to *good*: the stress on *good of J$\overset{3}{o}$hn* in isolation suggests that it is the Compound Rule which is applying. The Compound Rule (Chomsky and Halle 1968:17) results in the characteristics initial stress of English compounds: *bla$\overset{1}{c}$kb$\overset{3}{i}$rd* is produced by the Compound Rule while *bl$\overset{2}{a}$ck b$\overset{1}{i}$rd* is produced by the NSR. Thus we would have a derivation like that in Figure ~~#~~ 16.

```
  [It was [good [of John] ] [to leave] ]
            1    1   1             1      (word stress)
                 2   1                    1st cycle: NSR
                ---------
            1    3   2                    2nd cycle: Compound Rule
          -----------------
                                          3rd cycle:
    2            0   0                        syntax
  John
    3       2                      1          NSR
----------------------------------------
```

Figure # 16.

Notice that to avoid the derivation of **Mary was good of John to leave* by Object Shift from *It was good of John to leave Mary*, either the prepositional phrase *for NP* must be distinguishable by the rule from *of NP*, or else the infinitive must in these cases be an unreduced sentence at the point where Object Shift would apply.

[11] Since the ordering hypothesis entails that some phonological rules apply in deep structure or the lexicon, it is natural to ask whether all phonological rules so apply. It is clear that the rules of 'external sandhi' in some languages, affecting segments across word boundaries, must apply on surface structure, for two words which have separate locations in deep structure may be contiguous in surface structure and undergo sandhi. Such rules of 'external' phonological phenomena are analogous to the postcyclic or last-cyclic syntactic rules, in that both apply after the cyclic rules. Prosodic rules, such as the NSR, are analogous to cyclic transformations in a way that the ordering hypothesis makes clear. Word-internal rules affecting stress or segmental phonology (see Chomsky and Halle 1968) are analogous to rules of derivational morphology and doubtless interact with them. Further research pursuing the parallel articulation of phonological and syntactic rules and their interactions may prove interesting.

[12] Arlene Berman first pointed this consequence out to me, and Noam Chomsky called the further consequence for the lexicalist hypothesis to my attention.

[13] This formulation was suggested to me by James D. McCawley.

[14] This consequence was called to my attention by James McCawley.

[15] The problem posed by the dative was pointed out to me by Frank Heny.

[16] This problem was pointed out to me by Peter Culicover.

[17] This alternative was suggested to me by James McCawley.

[18] I have excluded the transformation Topicalization from discussion because topicalized sentences seem inherently emphatic or contrastive: *Jóhn I like*; *John I líke*. It is likely that many postcyclic transformations, because they create so-called stylistic inversions, are closely connected with contrast and emphasis.

[19] Because relative and interrogative clauses have special properties which prevent certain kinds of interactions with many of the better known cyclic transformations, it is difficult to prove from rule-ordering arguments that RCF and QF are cyclic. (See Ross (1967) for an exposition of some of these properties and a proposed explanation.) In Postal (1968a:26-27) an argument is presented that 'WH Q Movement' is not cyclic. Postal's argument is actually addressed to a version of QF unlike that assumed here. Here, QF is a Complementizer-Substitution Transformation in the sense of Bresnan (to appear): QF scans a S on every S-cycle, but only applies when its structural description is met--that is, when the S is complementized by WH [=Q]--and then QF substitutes the first eligible question word for WH. (See Bresnan (in preparation).) For example, the structural description

of QF is met only at S_2 in the following example, and so QF actually applies only on that cycle:

$[_{S_3}$ John asked me $[_{S_2}$ WH $[_{S_1}$ you thought $[_{S_0}$ he liked what]]]]

The derived sentence is John asked me what you thought he liked. Now the version of QF which Postal assumes permits the following kind of derivations:

John asked me WH you thought he liked what.→
John asked me WH you thought what he liked.→
John asked me what you thought he liked.

The question word (in this case, what) is brought to the front of every S until it reaches WH, or 'Q'. Postal notes that since QF optionally preposes prepositional phrases--

Who did you speak to?
To whom did you speak?

--this version of QF would allow prepositions to be 'stranded', producing ungrammatical strings; for example, in addition to the grammatical sentences

Who did she think you spoke to?
To whom did she think you spoke?

an ungrammatical string like this would result optionally

*Who did she think to you spoke?

by fronting the entire phrase to whom on the first cycle, but fronting only who on the next cycle. Because QF, under the version I am assuming, moves question words only into (and never from) WH complementizers, Postal's 'stranding' argument does not apply. But even the version of QF Postal assumes is not refuted by his argument, since the feature [+wh] could be assigned either to NP or to PP (Prepositional Phrase), and whichever node carried the feature would be shifted by QF throughout the derivation. (This possibility was mentioned to me by Noam Chomsky.)

[20] If Right Conjunct Reduction *merely* deleted material, the derived constituent structure would be wrong, for when *the news from France and the news from Italy* is reduced, *from France and from Italy* behaves as a prepositional phrase constituent under the Postposing rule, which will be discussed:

> The news is similar from France and from Italy.
>
> *The news from France is similar and from Italy.

For discussion distinguishing various kinds of conjunct reduction rules see Kuno (to appear) and the references cited there.

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On the Problem of Subject Structure in Language With Application to Late Archaic Chinese

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In current research on the grammatical structure of classical Chinese, efforts have been made to describe elementary constituents and their types and levels in reference to specifically chosen data.[1] Unfortunately, there appears to be two basic defects in this approach. First, in regard to the usefulness and adequacy of the categories which are used to characterize the language, there is no independent justification. Second, this approach seems to lend itself only to syntactical-formal considerations of the surface data, and fail to bring out the properties of the language as a system for communicating knowledge, information or meaning.[2]

To overcome the basic defect mentioned above, first of all, we should posit an overall theory in which grammatical categories are well defined. Secondly, we should treat sentences not simply as isolated items in a discourse, but instead as well-defined parts whose meanings and forms have an organic relation to other parts of the discourse. Thirdly, we should consider sentences as having more than one dimension of structure, namely, that of the surface syntax.

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[1] Cf. Studies made by W.A.C.H. Dobson: Late Archaic Chinese, University of Toronto Press, 1959; Early Archaic Chinese, University of Toronto Press, 1962; Late Han Chinese, University of Toronto Press, 1964; Chou Fa-kao: Chung Kuo ku-tai yu-fa, Ch'ao chu pien (A Historical Grammar of Ancient Chinese, Part I, Syntax), The Institute of History and Philology, Academia Sinica. Special Publications, no. 39, Taipei: 1961; Wang Li (ed.): Ku-tai han-yu (The Ancient Chinese), vol. I, Part 1 and Part 2, Peking: Chung Hua Book Co., 1962, 1964.

[2] Indeed it is true that in the study of classical Chinese, as in the study of other classical languages, we are dealing with a body of codified documents, with no immediate living speech corresponding to its content. Yet, this does not mean that we should not analyze the structure of the given data with a view to their actual function and use in communicating a subject matter.

In the analysis of the subject-predicate structure of classical Chinese there is want for adequate and well-defined criteria for determing the various types of subject-predicate structures. This is due to the absence of a general theory to explain the purposes of the analysis.

In this paper I shall start with general consideration of the distinction between subject and predicate and proceed to a relevant application of such distinction to any language. Once we have made this clear, it is only a corollary to show that subject-predicate structures in Late Archaic Chinese[3] can be systematically illustrated and logically explained. Specifically, I shall confine myself here to the analysis of the subject structure in language while leaving the treatment of the predicate structure to a separate article.

I. Philosophical Distinction between Subject and Predicate

Linguistic forms cannot be separated from all the uses to which they can be put. Among all the uses of linguistic forms, the most important and basic one is that for saying (or stating) how things are. For this purpose, [illegible] linguistic forms are capable of being asserted--which means that we are able to make reference to things or processes in the world we live in and we are able to say things about them. Our ability to make reference to things depends upon our ability to identify particular cases as well as the general types of things, and our ability to say things about things depends upon our ability to recognize the properties, general and particular, of things and the relations of things to other things including ourselves.[4] The transference between the particular and the general is exactly how the assertive and communicative function of language is achieved.

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[3] The use of the term is due to W.A.C.H. Dobson, first op. cit.

As noted by Strawson[5] among others[6] there is a certain asymmetry which essentially characterizes the referential and predicative functions of the linguistic form. In predications we attach some selected characteristics to a particular thing (referent), whereby excluding all other possible characteristics that may be used to describe that particular thing. The reason is that the stock of all possible characteristics may contain some mutually incompatible elements which cannot be used at the same time to characterize a particular thing. While we cannot always include all possible predicates (characteristics) of one thing at the same time, we can always refer to many things under a single predicate (characteristic) at the same time. This asymmetry is a logical criterion by which we can distinguish a thing from a characteristic and hence between reference and predication. Because we are able to refer to many things under a single predicate, we can make not only particular statements but also general statements of either universal quantification or existential quantification. Because we are able to attach certain characteristics to a particular thing, we can make informative statements and conceive our linguistic forms as a potential device for understanding the world.[7]

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[4] Austin prescribes that two types of convention are necessary to the possibility of our saying things about the world: *descriptive conventions* correlating words with general types of things and *demonstrative conventions* correlating words as uttered on particular occasions with particular situations to be found in the world. Cf. his paper "Truth," *Philosophical Papers*, Oxford: The Clarendon Press, 1961, pp. 89-90.

[5] In the introduction of the book *Philosophical Logic*, edited by him, Oxford University Press, 1967, p. 4.

[6] For example, Gottlob Frege, *Philosophical Writings*, (Peter Geach and Max Black, eds.) Oxford: Blackwell, 1952. Willard V. O. Quine: *Word and Object*, Cambridge: The M.I.T. Press, 1960.

The above account provides a ground for us to distinguish two basic functions of linguistic forms, namely, the referential function and the predicative function.[8] The linguistic form with the referential function can be called a logical subject, and the linguistic form with the predicative function can be called a logical predicate. The object which a logical subject stands for, i.e., the object to which a linguistic form is referentially directed can be called the ontic subject, whereas the characteristic or characteristics of the ontic subject which is predicated in the linguistic form, can be called the ontic predicate. Several things can be noted in regard to this distinction.

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[7] It is in this sense that our statement can be true and false and our language is basically referentially involved.

First, the referring expression of our sentence in general may not merely refer, but also contribute to the characterization of the types of situation ostensibly identified. Similarly, the predicative expression of our sentence may not merely predicate or ascribe characteristics to the referents but also include referential elements designating the temporal and spatial location of things. For general purposes we do not need to consider referring expressions as purely referential, for that means that they must be considered as variables of quantification. They can be considered as referring to individuals or particulars understood or specified in a particular universe represented or presupposed in the discourse.

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[8] There are other criteria for separating the referential from the predicative parts of a sentence. They are all related to this one and in fact equivalent to it. Frege has indicated that subjects are complete or saturated in a certain sense, i.e., in the sense that the thought of it is completely sensible. On the other hand, the predicates are incomplete or unsaturated in the sense that they will not indicate anything about the world unless they are "filled" with (and therefore are used to say about) things in the world. Cf. G. Frege's essay "On Sense and Reference," in Philosophical Translations from the Writings of Gottlob Frege; Oxford: Blackwell's, 1952; P. Geach in his book Reference and Generality, Chapter 2, and his paper "Assertion," Philo-

Secondly, referring expressions such as proper names and definite descriptions can be considered to be semantically meaningful, even though they are referential. They are referential and their predicative features need not concern us if these are understood in relation to either extralinguistic or linguistic or both contexts, the linguistic context being the discourse in which they occur. The extralinguistic context involves such things as the intentions and assumptions of the writers or speakers, and the circumstances to which the speech or writing is intended to apply.[9] In other words, referring expressions are referential in so far as they are so over a semantically specifiable discourse and context. Consequently, the referents (or the ontic subjects) of referring expressions is always categorized according to the discourse and context.[10]

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vol. 74, no. 4, 449-65.
sophical Review 1965, points out that we can negate a singular proposition by negating its predicate but not by negating its subject. The reason clearly is simple and related to the asymmetry noted here: i.e., whereas predicates have complementaries and contradictions, subjects do not have these at all.

[9] Cf. J.L. Austin, How to Do Things with Words, N.Y.: Oxford University Press, 1965, regarding the conditions of successful use of a sentence.

Thirdly, even though we can identify ontic subjects with actual or presupposed things and facts in the world, we do not have to assume existence of another kind for predicative expressions, namely things or facts other than the objects of referring expressions. Since controversies and technical difficulties are involved in developing a full theory of this, we simply maintain, along with Quine, but generally in opposition to Frege and Church, that ontic predicates are ontic subjects characterized in certain ways. Therefore at the lowest level the logical predicates can be said to have a divided reference (in Quine's terminology), because they can be applied to many individuals. The ontic predicates, in contrast to ontic subjects, are therefore ways in which things are understood once these things are identified as ontic subjects in a discourse.

II. Deep Structure and Surface Structure of A Language

If we assume that an ideal linguistic form is the logically simple (in whatever logical sense of simplicity) form for performing the functions of reference and

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[10] It is the same with the pure quantification variables to be defined in a discourse. In other words, for ordinary language, we can regard proper names as equivalent to quantificational variables of many sorts. This however will not prejudice our attitude toward the issues of eliminability of singular terms between Quine and Strawson. Cf. W.V.O. Quine: Word and Object, Cambridge: MIT, 1960; P.F. Strawson: Individuals, N.Y.: Anchor, 1963.

[illegible] predication, then we have a good reason as well as a good motivation to distinguish between the deep structure and the surface structure of a language. The deep structure of a language can be said to consist of those ideal linguistic forms which can perform the functions of reference and predication with greatest logical simplicity. The surface structure, on the other hand, consists of linguistic expressions (phonological or morphological) which exhibit the deep structure forms but which however often results from various combinations of the deep structure forms for pragmatic considerations. In this sense the surface structure of a language is logically more complicated, even though pragmatically more facile, than the deep structure, and is derived from the deep structure by way of transformations.

Methodologically, we need transformations (or rules of transformation) if we want to preserve the correlation between a surface structure sentence and the corresponding constituent deep structure sentence or sentences. For in the surface structure a given actualized sentence produced in the learning or use situation does not exactly correspond *simpliciter* to idealized linguistic forms which exhibit the functions of reference and predication and their interconnections in the deep structure.[11] This distinction between deep structure and surface structure of a language has been made quite clear in Chomsky's work.[12] Chomsky posits the deep structure of a language for the purpose of accounting for real structural differences of sentences with apparent structural similarity such as found in the pair:

---

[11] The rules of transformations are logical possibilities, not real laws, which we can adopt to analyze the surface structure sentences to make their functions of reference and predication explicit and clear under

> I persuaded John to leave.
> I expected John to leave.

or for uniquely determining the meaning of structurally ambiguous sentences such as:

> Flying planes can be dangerous.
> I learned the shooting of lions.[13]

Deep structure is also used to account for structural relations such as those between passive voice and active voice and between questions and statements.

Although the above are valid reasons for making a distinction between the deep structure and the surface structure of a language, it is to be noted that our reason for such a distinction is a more fundamental one. For us the deep structure is a logical structure which fulfils an ontological purpose and therefore

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considerations of simplicity. In other words, the deep structure is the simplest model of a language whose surface structure can be derived through a simple set of rules of transformation.

[12] See Noam Chomsky: Aspects of the Theory of Syntax, Massachusetts: The MIT Press, 1965, 16-18, 64 ff. Also Jerold J. Katz: The Philosophy of Language, New York: Harper and Row; 1966, 131 ff, 138 ff; P. Postal, "Underlying and Superficial Linguistic Structures," Harvard Educational Review, vol. 34, no. 2, 1964.

[13] The first three are taken from N. Chomsky, op. cit. 21-22.

is not merely part of a formal scheme. It is in fact an interpretated scheme, interpretated in terms of things and their characteristics with full consideration for reference and predication underlying every linguistic expression.

Specifically, our scheme differs from Chomsky's in two respects: 1) The semantic component in Chomsky's scheme is separated from the syntactic base component, whereas in our scheme they are intimately integrated. 2) As we shall see, even though a sentence in its deep structure may differ from its derived counterpart in the surface structure, they share in common the same ontological significance. Because of this, the linguistic forms in the deep structure are intimately related to their uses in the surface structure. They are therefore not to be correlated merely by logically simple rules of transformation. In fact, they are correlated by transference of the ontological significance of the deep structure sentence which is preserved after the application of transformations. Rules of transformation apply only to the syntactic component or form, while they leave the semantic component or meaning intact.

With the referential and predicative functions properly assigned to the ontic subject and ontic predicate respectively, we can adopt Chomsky's NP and VP to respectively designate our purely formal logical subject and logical predicate. According to Chomsky, a formal definition of logical subject and predicate is as follows:

1) Subject of: /_NP, S_7
2) Predicate of: /_VP, S_7 [14]

In order to apply these definitions of the logical subject and logical predicate to our case it is necessary for us to formulate a principle governing the context of the deep structure with respect to the whole discourse. The principle is this. The NP occupying the position of a logical subject in the deep structure must appear at least once in the surface structure as exhibited by a well-defined discourse. The same holds for VP which occupies the position of a logical predicate. We can call this principle the verification principle for the deep structure. Chomsky does not seem to have ever made explicit such a principle.

In terms of the verification principle for the deep structure, as well as the basic considerations for the communicative, i.e., referential and predicative functions of language, the deep structure can be conceived as an ideal form-meaning composite underlying the actual expressions in the surface structure. This concept of deep structure represents a deviation from Chomsky's original formulation of deep structure with some significant consequences. Clearly one consequence, *inter alia*, is that syntax is no longer separated from the semantics of reference and predication in the deep structure of a language. In this sense this deviation is in fact an improvement.

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[14] Chomsky: Ibid., p. 71.

Now let us proceed to characterize the content of the surface structure. In the first place, we shall not forget that a sentence in the surface structure, like one in the deep structure, is only part of a discourse, related to linguistic and extralinguistic contexts. In other words, sentences are used to perform certain various functions in the surface structure on the basis of the referential and predicative function.[15] We will confine ourselves to the fact that a sentence in the surface structure may differ structurally from its corresponding sentence in the deep structures. These differences arise primarily as a result of expressing our thought under various pragmatic considerations. For example, we use sentences in the passive voice for accentuating the reverse relation of action, or for describing actions without presupposing knowledge or reference to their agents. Furthermore, we use impersonal pronouns, such as "it" in English as a dummy grammatical subject to indicate something which we are familiar with, but which we cannot definitely and precisely specify , or to represent a state of affairs which can be or will be specified in another context, temporally or logically prior to the given one.

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[15] Here we shall not enumerate such functions. See Austin, op. cit.

We make deletions of subjects or predicates in a discourse or linguistic and/or extralinguistic contexts when there is no practical risk of confusion and/or there is a gain in simplicity.

In our present discussion we cannot give explanation for all the grammatical and syntactic features of sentences in the surface structure. Suffice it be recognized that all the grammatical paraphernalia in the surface structure are either pragmatically or contexually justified or both. This implies that when there are more or less items in the surface structure than in the corresponding deep structure, it is assumed that they are added or subtracted for pragmatic reasons, but not for logical [illegible] or ontological reasons. How large these discrepancies are and to what extent as well as in what ways between the deep structure and the surface structure depend on individual languages. One can of course always assume a universal or very general deep structure for all languages, as Chomsky appears to do. If we adopt this assumption, we can perhaps compare different surface languages in terms of the underlying universal deep structure. Thus, perhaps one can say that whereas the surface structure of English appears to add more than necessary in the corresponding deep structure, the classical Chinese (wen yen in general) tends to reduce what is needed in an adequate description of the deep structure by way of deletions and so on.

III. Two Characteristics of Sentences in the Surface Structure

If we can grasp the distinction between the deep structure and the surface structure of a language in the sense we have intended above, we can now proceed to make distinctions in regard to the surface structure alone. These are the distinctions between a grammatical subject and a grammatical predicate on the one hand and the distinction between topic and comment on the other.

A good way to explain the distinction between a grammatical subject and a grammatical predicate is in terms of the phrase-structure markers NP and VP. The NP in a surface structure sentence of the form NP+VP is always a grammatical subject, whereas the related VP is always a grammatical predicate. Whether this corresponds to a deep structure distinction is another question. It is not necessary that this does. In other words, we assume that we can identify the S = NP + VP construction in the surface structure without assuming that the NP is in fact logically referential or the VP is in fact logically predicative. For NP and VP in the surface structure can be related in all sorts of ways. In general, perhaps we have to assume certain formal criteria for making the the grammatical distinction in question. These formal criteria will make reference to the transformation rules by which they can be shown to be formally related to the underlying logical structure. For example, one formal criterion for a full sentence in Chinese (ancient as well as modern) is that the only noun phrase which physically precedes the verb phrase is always the grammatical subject.

Now as to the topic-comment distinction, Chao Yuan-ren has explained it as a distinction between the subject-matter to talk about and the remarks said about the subject-matter.[16] In these general terms, the topic and comment distinction seems to correspond to the distinction between reference and predication. But in fact, a topic is more broadly conceived than a reference: for any expression, complete or incomplete, can be a topic, but not every expression in fact is referential, nor any comment in fact is predicative with respect to a given topic in the sentence. The distinction between topic and comment however bring out some surface connections between linguistic items in sentences. These various surface connections remain to be analyzed in terms of different categories.

At this point, one might wonder what purpose will be served in drawing a distinction between topic and comment apart from providing a basis for further analysis. However, in order to give a full significance to the distinction in question, we may suggest that the comment represents the focus of attention or an act of knowing and the topic represents the background in which the focus is related to other things (points) of interest. Construed in this way, the distinction between topic and comment therefore pertains to sentences (or language) in actual use, and consequently is closely linked to extralinguistic factors such as the awareness of the speaker or the listener. It is in the consideration of the context of use, the topic can suggest, even though it does not fully symbolize, the grammatical or logical subject of the sentences for which the comment is grammatically or logically relevant.[17]

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[16] See Chao Yuan-ren, A Grammar of Spoken Chinese, preliminary edition, University of California Press, 1965, 90 ff. Chao contrasts the distinction between topic and comment on the one hand and actor-action distinction on the other.

In so far as a topic suggests the logical subject and/or the grammatical subject, and the comment on the topic serves as the center of interest or focus of attention in the speech situation, a topic can be called a psychological or epistemological subject, and relative to this, a comment can be called a psychological or epistemological predicate, i.e., that part of speech on which the point of message or information falls.[18]

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[17] Cf. A.M. MacIver, "Demonstrations and Proper Names," in Philosophy and Analysis, edited by Margaret MacDonald, Oxford, Beachwell, 1954, 26-32.

[18] In this regard, we note that Chao Yuan-ren distinguishes topic from the "logical subject" in the sense of our psychological or epistemological subject. On the other hand, we do not make such distinction, but instead we define implicitly topic in terms of psychological or epistemological subject, and distinguish it from the logical subject in the deep structure of a

According to a suggestion by Chao,[19] the psychological or epistemological predicate in a sentence can be brought into a prominent place in the sentence by "constrastive prosodic stress," or by magnified length and pitch range. Indeed the psychological or epistemological predicate can be indicated also by acts of non-speech such as gestures or other tokens. This indicates that topic and comment in the sense of psychological or epistemological subjects and predicates sometimes can be revealed only in actual speech situations. But since ancient Chinese, which we are going to deal with, is codified in nonphonetic script, we might adopt the convention that (1) the beginning position of a sentence is always reserved for the topic of the sentence and the rest for the comment, and (2) in case of a minor sentence,[20] the whole sentence is a comment.[21]

IV. Four Levels of Analysis of the Subject Structure

In the above we have seen that a language has two

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language. Chao's characterization of the "logical subject" corresponds to Cook Wilson's characterization of the same. Cf. Cook Wilson, Statement and Inference, vol. I., Oxford: Clarendon Press, 1926, 119 ff. Quoted in Chomsky, Ibid., 163, Cf. also Chao, Ibid., 102 ff.

[19] Chao, op. cit., 103.

[20] A minor sentence is not of the subject-predicate form in the surface structure, Cf. Chao, op. cit., 77. See also section 5.

[21] By the very nature of a comment, a comment demands attention and therefore exposition. A topic, on the other hand, is often suppressed in known linguistic con-

levels--the deep structure and the surface structure. The deep structure sentence is an idealized reconstruction of a corresponding surface dtructure sentence in the light of the consideration of the whole discourse and in accordance with the linguistic functions of reference and predication preserved in a logically simple form. It contains therefore the ontic subject and the ontic predicate on the one hand, and the logical subject and the logical predicate on the other. The surface structure sentence is a natural language sentence in its actual use conforming to a pragmatically-oriented grammar. In terms of this grammar, it can have a grammatical subject and a grammatical predicate. In terms of its use for communication, it can have a topic and a comment (the psychological/epistemological subject and predicate).

It is clear that these four levels of the subject and predicate structure distinguished above are interrelated and interdependent. We must realize that the answer to the question as to exactly how these four levels are related completely depend upon individual languages. In English writing (not in speech), for example, the grammatical subject is almost a must and can be always identified in the relevant linguistic discourse or context. On the other hand, in Chinese, the grammatical

[illegible]

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texts or extralinguistic situations in which knowledge of the topic is presupposed or the topic is in fact strongly suggested.

subject is not necessarily identifiable in the context. In other words, it is logically (not just pragmatically) dispensable, and this is the basis of the classification of what I call essentially subjectless sentences.[22] Of course, we must point out that in the analysis of the subject structure in any language, the ontic subject and the ontic predicate are always presupposed. They are to be determined through consideration of the whole discourse and possible extralinguistic factors under which the language was or possibly was used.

Now once we have determined the ontic subject and the predicate, we can proceed to determine, on the evidence of the given discourse, what the logical subject and logical predicate are, i.e., those linguistic expressions (or forms) which stand for (or symbolizes) the ontic subject and the logical predicate. In this sense, the logical subject and the logical predicate. coincide with the ontic subject and the ontic predicate by the semantical relation of "designating" and "being true of." Given the determination of these we can of course proceed to ask whether a given surface sentence in the discourse coincides with a deep structure sentence. The answer is that the logical subject and the logical predicate need not be the same as the grammatical subject and the grammatical predicate. This means that the logical subject-expression and the logical predicate-expression need not be the same as the grammatical subject-expression and the grammatical predicate-expression. One has to inquire into how the surface sentence is derived from the deep structure sentence by transformation rules.

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[22] For clarification of this, see later discussion.

Just as the logical subject and predicate need not be the same as the surface grammatical subject and predicate, one can see that the grammatical subject and predicate need not be the same as the topic and comment or psychological/epistemological subject and predicate. For each pair is specified according to a different and distinctive criterion and there is no contradiction nor incompatibility in their being different. This only shows how the various aspects of a sentence must be revealed in a rich theory.

In the light of the above analysis, it is clear that for a full understanding of a sentence, it is necessary that we should look into its subject-predicate structure on these four levels: the ontic and the logical in the deep structure and the grammatical and psychological/epistemological in the surface structure. To analyze this structure. one can begin with the surface structure distinctions and work into the deep structure distinctions, or one can proceed reversely. A linguistic specification of a sentence in regard to its subject-predicate structure must be therefore four-valued: in terms of the values of the ontic subject and predicate, the values of the logical subject and predicate, the values of the grammatical sub-...............................

ject and predicate, and the values of the psychological/epistemological subject and predicate. The values of the ontic subject and prediate are the actual objects and attributes determined by the discourse. The values of the logical subject and predicate are the subject-expressions and predicate-expressions standing for the predetermined ontic subjects and predicates; the values of the grammatical subject and predicate are the subject-expressions and predicate-expressions introduced by transformation rules; finally the values of the psychological/epistemological subject and predicate are the linguistic expressions which serve to provide a background of knowledge and at the same time to introduce new items of information as the focuses of attention.

An important point about the four-level characterization of the subject-predicate structure is this. Whereas the ontic subject and predicate in the deep structure are always present (this is due to our assumption of the basic assertive or communicative functions of our language), and the psychological/epistemological subject and predicate in the surface structure are also always present (this is due to the fact that the topic-comment structure is a necessary condition for the actual use of a sentence), the logical subject and predicate in the deep structure and the grammatical subject and predicate in the surface structure are not always present. In other words, a sentence must be analyzable with regard to a pair of specifiable ontic subject and predicate on the one hand and a pair of specifiable topic and comment on the other, it need not be analyzable with regard to a pair of specifiable logical subject and predicate and/or a pair of specifiable grammatical subject and predicate.

The foregoing point may appear to be surprising. But in the light of the following facts, our surprise need not prevent us from perceiving the truth of the foregoing point: (1) the topic and comment need not coincide with the grammatical subject and predicate or the logical subject and predicate and vice versa. (2) The ontic subject and predicate are different in kind from the logical subject and predicate. (3) The logical subject and predicate need not coincide with the grammatical subject and predicate. (4) No logical subject-expression and logical predicate-expression need be evidenced in the given discourse, even though they can be suggested, (5) The grammatical subject and predicate can be deleted or added through certain transformation rules. On the basis of these facts, it is natural to expect that either the logical subject and predicate or the grammatical subject and predicate or both may be missing (and therefore theoretically dispensable) from the given sentence. On (4) alone, due to considerations of the verification principle, the logical subject could be absent. On (5) alone, due to considerations of transformation, the grammatical subject could be absent. On both (4) and (5), both the logical subject and the grammatical subject could be absent. To say this however is not to say that language activity may not fulfil its intended purpose of communication. The reason why it does not consists in the fact that the deep level of the deep structure and the surface level of the surface structure of a language always provide a framework in terms of which reference, predication, and therefore communication, can be understood and indeed reconstructed.

Because of the possible absence of the logical or the grammatical subjects or both from a given sentence, we can generally describe the subject structure of a sentence in terms of the four levels and by noting whether it has or has not a logical or grammatical subject, or has both or neither.

Summarizing the above, our scheme of four levels of analysis of the subject structure of a sentence can be represented as follows:

Levels / Cases	DEEP STRUCTURE		SURFACE STRUCTURE	
	ontic subject	logical subject	grammatical subject	topic or comment
Case I	+	+	+	+
Case II	+	+	-	+
Case III	+	-	+	+
Case IV	+	-	-	+

Given the case that the logical subject and the grammatical subject are present in the analysis of a sentence, we face another question the answer to which is essential for specifying the subject structure of the sentence. The question is whether the existent logical subject coincides with the grammatical subject, whether it coincides with the topic, and finally whether grammatical subject in fact coincides with topic. If we let L stand for the presence of the logical subject, $\overline{L}$ for the absence of the logical subject, G the presence of the grammatical subject, $\overline{G}$ the absence of the grammatical subject, T the presence of topic or comment. We have the following eight possible cases in the analysis of the subject structure of a sentence:

Case I: (L, G, T)

sub-case i: $L = G = T$
sub-case ii: $L = G \neq T$
sub-case iii: $L \neq G = T$
sub-case iv: $G \neq T$, $T \neq L$, $L \neq G$

Case II: (L, $\overline{G}$, T)

Case III: ($\overline{L}$, G, T), Sub-case i: $G = T$; sub-case ii: $G \neq T$

Case IV: ($\overline{L}$, $\overline{G}$, T)

The question may be raised as to why Case II does not admit of sub-cases i) $L = T$, ii) $L \neq T$. The reason for this is that in the absence of the grammatidal subject, T will always be identical with the grammatical predicate and hence will not serve the purpose of reference. This means that it cannot coincide with L. One can also note the rarity of Case I, sub-case iv, i.e., the case of (L, G, T) where $G \neq T$, $T \neq L$, $L \neq G$. This rarity can be explained as a result of the presence of very strong transformation restrictions.

Since the classical Chinese, particularly Late Archaic Chinese, to which we shall apply our analysis, is rich with the subjectless sentence, we shall note here a distinction between the relatively subjectless sentences on the one hand and the essentially subjectless sentences on the other:

1) Relatively subjectless sentences are those whose grammatical subjects are understood in a linguistic context and are normally identifiable in preceding sentences in a connected discourse. The grammatical subjects are deleted by a deletion rule. They do not lack logical subjects, for, on the verification principle, the deleted grammatical subjects can be regarded as being present in the deep structure as logical subjects.

2) Essentially subjectless sentences are those which have no grammatical subjdcts as well as no logical subjects, but whose ontic subjects can be identified in the immediate extralinguistic contexts of their use. There are no certain definite terms or definite descriptions in the preceding or succeeding linguistic contexts to identify their logical subjects. Yet one may "reconstruct" their logical subjects as terms or expressions referring to something or everything or anything of certain categories. Hence the essentially sub-

jectless sentences are of two kinds:

i) Their ontic subjedts are "something" of a certain category and hence are equivalent to referents of indefinite descriptions or ranges of values of variables of existential quantification.

ii) Their ontic subjects are "everything" or "anything" of a certain category and hence are equivalent to ranges of values of variables of implicit universal quantification of various scopes.

It is clear that the relatively subjectless sentences belong to case II, whereas the essentially subjectless sentences belong to case IV. These two kinds of the subjectless sentences have not been distinguished in studies on the grammar of the classical Chinese.[23]

V. Application to Late Archaic Chinese

We will now apply the above theory of the subject-structure to the analysis of the subject structure in the Late Archaic Chinese. This will not only serve the purpose of clarifying the subject-structure of Late Archaic Chinese, but will illustrate the usefulness of the general theory presented above.

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[23] E.g. Chou Fa-kou, op. cit., 6 ff, and W.A.C.H. Dobson in his Late Archaic Chinese, fail to make this distinction and therefore fail to appreciate the intricacy and significance of the distinction. The reason is simple, they do not have a sufficiently rich theory to characterize the various aspects of the subject-structure of a sentence in the classical Chinese.

In all the following examples, we shall note stylistic eccentricities, their semantical characteristics as well as their general frequencies in the classical texts.

Case I (L, G. T),

Sub-case i: L=G=T, most frequently instantiated.

1) 君 子 不 憂 不 懼 (論語,顏淵)
Chün tzu pu yu pu chü
Superior man not worry not fear
The superior man does not worry nor fear. (*The Analects*, 12.4)

君子 (The superior man) = L = G = T

2) 孟 子 見 梁 惠 王 (孟子,梁惠王上)
Meng tzu chien Liang Hui Wang
Meng Tzu see Liang Hui King
Meng Tzu saw King Hui of Liang. (*The Mencius*, 1.2)

孟子 (Meng Tzu) = L = G = T

3) 仁, 內 也, 非 外 也; 義, 外 也,
Jen, nei yeh, fei wai yeh; yi, wai yeh,
Benevolence, internal, not external; righteousness, external,
Benevolence is internal not external; righteousness is
非 內 也. (孟子,告子上)
fei nei yeh.
not internal.
external, but not internal. (*The Mencius*, 11.4)

仁 (benevolence) = L = G = T
義 (righteousness) = L = G = T

Sub-case ii: L=G≠T, frequently instantiated.

1) 水 火, 吾 見 蹈 而 死 者 矣, 未 見 蹈
Shui huo, wu chien tao erh ssu che yi, wei chien tao
Water fire, I see step and die, not see step
I have seen men stepping on water and fire to die, but
仁 而 死 者 矣. (論語,衛靈公)
jen erh ssu che yi
benevolence and die.
have not seen men stepping on benevolence to die. (*The Analects*, 15.35)

水火 (water and fire) = T
吾 (I) = L = G

2) 萬 乘 之 國， 弒 其 君 者，
Wan ch'eng chih kuo, shih chi chün che,
Ten thousand carriages state (kingdom), kill its ruler,
In the case of a state of ten thousand carriages, the one

必 千 乘 之 家 (孟子，梁惠王上)
pi ch'ien ch'eng chih chia.
must ten hundred carriage family.
who will kill his ruler must be [from] a family of ten hundred carriages. (The Mencius, I.1)

萬乘之國 (a state of ten thousand carriages) = T
弒其君者 (the one who will kill his ruler) = L = G

3) 野 哉 由 也 (論語，子路)
Yeh tsai Yu yeh
Rude Yu
Yu is rude. (The Analects, 13.3)

野哉 (rude) = T
由 (Yu) = L = G

Sub-case iii: $L \neq G = T$, not frequently instantiated.

1) 道術 將 為 天 下 裂 (莊子 天下篇)
Tao shu chiang wei tien hsia lieh
The art of Tao will be the world break (destroy)
The art of Tao will be broken by the world. (Chuang Tzu, "On the World")

天下 (the world) = L
道術 (the art of Tao) = G = T

2) 吾 長 見 笑 於 大 方 之 家 (莊子，秋水篇)
Wu ch'ang chien hsiao yu ta fang chih chia
I always see laugh at great way masters
I should always have been laughed at by the Masters of the Great Way. (Chuang Tzu, "The Autumn Flood")

大方之家 (the Masters of the Great Way) = L
吾 (I) = G = T

3) 勞 力 者 治 於 人 (孟子，滕文公上)
Lao li che ch'ih yu jen
Labor force persons govern at men
The bodily workers are governed by others. (The Mencius, 5.4)

人 ([some] men) = L
勞力者 (the bodily workers) = G = T

Sub-case iv: $G \neq T$, $T \neq L$, $L \neq G$ rarely instantiated. This case is very rare in Late Archaic Chinese, and perhaps rare in any language, as we have pointed out earlier. The reason for this is that the existence of an instance of the case depends upon the reversion of anpassivecf the voice which is already indirect. But conceivably we could have a sentence of the form 今盆成括為齊王所殺("Now Pen Ch'eng-kua was killed by the King of Ch'i") where 今(now) = T, 齊王 (The King of Ch'i) = L, 盆成括(Pen Ch'eng-kua) = G. The closest actual example which I have found in the classical texts is the following: 昔者，龍逢斬，比干剖，萇弘胣，子胥靡。(莊子，胠篋篇) ("In the past, Lung Feng was beheaded; /_the heart of_7 Pi Kan was cut open; /_the bowels of_7 Ch'ang Hung was cut open; /_the body of_7 Chi Hsü was made to rot." Chuang Tzu, "Opening Brief"), where the logical subject in each constituent sentence has to be supplied on the basis of the verification principle for the deep structure.

Case II (L, $\overline{G}$, T), frequently instantiated. Consider the sentences taken from 孟子，公孫丑上(The Mencius, 3.2)

/_1'_7 非其君 /_1_7 不事

fei ch'i chün pu shih
not his ruler not serve
If /_any ruler_7 is not his type of ruler, /_Pei Yi_7 will not serve /_him_7.

/_1''_7 非其民 /_1_7 不使

fei ch'i min pu shih
not his people not command
If /_any people_7 is not his type of people, /_Pei Yi_7 will not command /_them_7.

/_2'_7 治 /_2_7 亦 進

ch'ih yi chin
well-governed too advance
If /_a state_7 is well-governed, /_Yi Yin_7 will advance /_himself to an office._7

/_2'_7 亂 /_2_7 亦 進

luan yi chin
out of order too advance
If /_a state_7 is out of order, /_Yi Yin_7 will too advance /_himself to an office_7.

/_3_7 可 以 仕 /_3_7 則 仕
k'o yi shih tse shih
can become an official then become an official
When /_Kung Tzu_7 found it possible to become an official, /_Kung Tzu_7 would become an official.

/_3_7 可 以 久 /_3_7 則 久

k'o yi chiu tse chiu
can stay long then stay long
If /_Kung Tzu_7 found it possible to stay long, he would stay long.

/_4_7 皆 古 聖 人 也
chieh ku sheng jen yeh
all ancient sage
/_Pei Yi, Yi Yin, and Kung Tzu_7 were all ancient sages.

乃 /_5_7 所 願， 則 /_5_7 學 孔 子 也
Nai so yuan, tse hsüeh Kung Tzu yeh
As to what is wished, then learn Kung Tzu
As to what I wish to be, I wish to follow Kung Tzu.

The brackets /_1_7, /_2_7, /_3_7, /_4_7, /_5_7, in these sentences without grammatical subjects, indicate the presence of logical subjects which can be located in the immediate or immediately enlarged contexts of the discourse. In fact they are explicitly identified by Mencius. Thus these sentences are relatively subjectless and have the type of subject structure (L, $\bar{G}$, T), whereby /_1_7 = 伯夷 (Pei Yi) = L, /_2_7 = 伊尹 (Yi Yin) = L, /_3_7 = 孔子 (Kung Tzu) = L, /_4_7 = 伯夷, 伊尹, 孔子

(Pei Yi, Yi Yin, Kung Tzu) = L, [5] = 吾 (I = Meng Tzu) = L.

Case III ($\bar{L}$, G, T)

Sub-case i: G = T, frenquently instantiated.

1) 有朋自遠方來，不亦樂乎
Yu p'eng chih yuan fang lai, pu yi lo fu?
Have friend from distance come, not also delightful
If a friend comes from afar, is that not a delightful thing?
(The Analects, 1.1)

Here the sentence is of the form $(S + P_1) + P_2$ or $(S = NP + VP_1) + VP_2$. Hence it does not have the logical subject in the defined sense, but it has the grammatical subject and the topic which is 有朋自遠方來 (there is a friend coming from afar).

2) 夫惟病病是以不病 (老子，道德經，五十九章)
Fu wei ping ping shih yi pu ping
Only sick sick thus not sick
Only when one is sick of [one's] sickness, is [one] not sick. (Lao Tzu: Tao Te Ching, 59)

夫惟病病 (Only [when one is] sick of [one's] sickness) is not the logical subject of the whole sentence, but the grammatical subject and the topic of the sentence.

3) 過而不改，是謂過矣。(論語，衛靈公)
Kuo erh pu kai shih wei kuo yi
Fault and not correct, this called fault
If one has faults and does not correct them, this is then called a [real] fault. (The Analects, 15.30)

"是 (this)" is a grammatical subject as well as a topic. It is not a logical subject, nor is its referent "過而不改 (having faults without correcting them)" the logical subject of the sentence in the defined sense.

Sub-case ii: G ≠ T, not frequently instantiated.

1) 大 哉 堯 之 為 君 也 (論 語, 泰 伯)
Ta tsai yao chih wei chün yeh
Great Yao's act as ruler
Great is [the way in which] Yao acted as a ruler.
(The Analects, 8.19)

堯之為君也 ([the way in which] Yao acted as a ruler) = G.

大哉 (great!) = T

2) 久 矣 吾 不 復 夢 見 周 公 (論 語, 述 而)
Chiu yi wu pu fu mêng chien Chou kung
Long I not again dream-see Chou duke
For long I have not dreamed of Duke Chou. (The Analects, 7.5)

吾不復夢見周公 (that I have not dreamed of Duke Chou) = G
久矣 (for long) = T

Both examples are of the sentence form $P_1 + (S + P_2)$ or $VP_1 + (NP + VP_2)$ where $(S + P_2)$ or $(NP + VP_2)$ is the grammatical subject and P_1 or VP_1 is the topic.

Case IV ($\bar{L}$, $\bar{G}$, T), frequently instantiated.

In Case II we have dealt with the relatively subjectless sentences. In the present case (Case IV) we will deal with essentially subjectless sentences. In connection with the examples of Case II, we can see that the brackets [1'], [1"], [2'] which represent the missing grammatical subjects are not to be located in the immediate or immediately enlarged contexts of the discourse. Hence the related sub-sentences are essentially subjectless. These sentences are understood in the context to refer to something or some class of things of a certain category. Thus, [1'] = any ruler, [1"] = any people, [2'] = any state or the world, Other types of examples of Case IV are the following:

1) 雨 我 公 田，遂 及 我 私（詩，小雅，大田）
Yü wo kung t'ien, sui chi wo ssu
Rain I public field, and reach I private
Rain over my public field, and so over my private one.
(*The Book of Poetry*, *Smaller Odes*, "Large Field")

雨 (rain over) = T
我公田 (my public field) = locative.

2) 庚 辰，大 雨 雪。（春秋，隱公九年）
Keng ch'en, ta yü hsüeh
Keng-ch'en big rain snow
In the year of Keng-ch'en, [there was] a big snow-storm. (*The Annals of Spring and Autumn*, "Duke Yin, Ninth Year)

庚辰 (in Keng Ch'en year) = T
大雨雪 ([there was] a big snow-storm) = comment

3) 有 朋 自 遠 方 來（論語，學而）
Yu p'eng chih yuan fang lai
Have friend from afar come
There is a friend coming from afar. (*The Analects*, 1.1)

"有 (yu)" has the function of changing a definite term such as "朋" into an indefinite term. But this transformation does not determine a grammatical subject for the sentence to which it belongs. For apparently neither "朋" nor "有朋" nor "有" can be condidered the grammatical subject of the sentence. One might argue that "有朋" determines a logical subject. But then the difficulty is that this apparent logical subject is not "realized" in any grammatical subject. Here we simply decide that sentences of 有無 yu/wu type simply are essentially subjectless. Their ontic subjects are to be referred by indefinite descriptions such as "有朋".

The topic as well as the comment of 3) is the

the whole sentence as it stands.

Instances similar to 3) can be multiplied, for example, 4).

4) 今有一人入人園圃(墨子,非攻上)

5) 未有仁而遺其親者也(孟子,梁惠王上)
Wei yu jen erh yi ch'i ch'in che yeh
Not have benevolence and forget his parents .
There is no person who is benevolent but who forgets
his parents. (The Mencius, 1.1)

未有仁 (no person who is benevolent) = T

6) 未能事人,焉能事鬼?(論語,先進)
Wei nêng shih jen, yen nêng shih kuei
Not able serve man, how can serve ghosts
If [one] is not able to serve man, how can one serve
ghosts? (The Analects, 11.12)

未能事人 ([one] is not able to serve man) = T

7) 未知生,焉知死?(論語,先進)

8) 非夫人之為慟而誰為?(論語,先進)
Fei fu jen chih wei t'ung erh shui wei
Not that man grieve who should
If [I] do not grieve for that man, for whom should I
grieve? (The Analects, 11.12)

非夫人之為慟 (if [I] do not grieve for that
man) = T

Of course, in this instance one might consider "I" (referring to Kung Tzu himself) as understood in the context of saying and thus there is an implicit logical subject of the sentence. The possibility of this interpretation applies to the following instance:

9) 由也,千乘之國,可使治
Yu yeh ch'ien ch'eng chih kuo, k'o shih ch'ih
Yu one thousand carriages state, may let govern
Yu [is such a person that] a state of a thousand car-
其賦也(論語,公冶長)
ch'i fu yeh
its military system.
riages may put him in charge of its military system.
(The Analects 5.8)

Both 由也 (Yu) and 千乘之國(a state of a thousand carriages) can be regarded as topics.

A Proposal concerning Question-words

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The past few decades have witnessed the development of an approach to linguistics which aims at a linguistic theory adequate to account for the data on observational, descriptive, and explanatory levels. This approach often begins with Saussure's distinction between langue, the abstract language system, and parole, the actual speech in daily use. Chomsky, recapitulating the Saussurian dichotomy in terms of competence and performance, claims that linguistics is properly the study of intrinsic competence, to be expressed as a formal system which would generate all and only those sentences acceptible to a native speaker of the language, which in turn is assumed to have come from an ideal, homogeneous speech community. Much discussion has been directed toward competence and performance, the native speaker's judgment, and the homogeneity of the speech community and I do not intend to give a coverage of the arguments here. However, in connection with the present study I shall examine the role of sentence which is the output of a grammar and supposedly the most fundamental unit of linguistic analysis. In Section 1 of this paper the assumed completeness and autonomy of a sentence as commonly held by the structuralist is duly (and overduly) challenged.

With an understanding that grammar is a set of rules mediating between thought and speech and correlating sound and meaning, we are concerned about the nature of grammatical rules. With a belief that the need for communication is basically the same for all human beings and that meaning can be formulated into an absolute system, we require the set of grammatical rules for each individual language to perform the function of deriving the particular from the universal, i.e., to generate a set of utterances whose structure is unique for every language concerned from the universal semantic deep structure which is comparable to a formal logical system. What, then, motivates and constrains such transformational operations that give us the superficial structures found in actual speech? Can we explicitly state the conditions under which a thought takes shape in the forms of a particular language? We shall try by way of a critical examination of current practice in the area of transformational constraints to find an answer to our questions.

Thirdly, in connection with my study of case relation, topicalization, and anaphoric processes for Chinese and Amis, a Formosan aboriginal language, I become convinced that questions, whether explicit or implicit, play a central role in the semantics of natural languages. Questions ask for information; questions are goal-oriented. For a language to be a true communicative system, it should demonstrate a sequence of stimuli and responses which would lead to interactions of ideas and exchange of information. If it is possible to discover a semantically justified universal syntactic theory, and if it is possible to relate the deep structure to surface forms by means of grammatical rules, then somewhere along the lines of Fillmore's case grammar one should include question-words as part of the base component. The justification for doing this would become self-evident as we take up this issue with examples in Section 3. For the time being it suffices to say that the inclusion of question-words in the base component would not only facilitate semantic interpretation on the grounds of language universals but also offer a possible solution to some problems concerning the derivational procedure from the base to the surface structure.

1. The structuralist's concept of a sentence.

In his Introduction to Theoretical Linguistics, Lyons sums up Bloomfield's definition of the sentence as follows: the sentence is the maximum unit of grammatical description to which the structuralist's notion of distribution is not applicable. In other words, a sentence is distributionally independent except for some 'practical connexion' with other parts of the discourse.

With this definition in mind, let us examine the so-called 'derived' sentence. For example, sentences involving the use of pronouns are considered 'derived' because their understanding depends on the hearer's ability to substitute for the pronouns the correct nouns or noun-phrases previously given, explicitly or implicitly, in the context. If we should extend this mode of reasoning, a proper noun like 'John' would be just as meaningless as a pronoun unless the existence of that particular individual named John and some knowledge of John's being are presupposed. The same argument applies also to common nouns with definite articles. To further pursue this issue, one would arrive at the point that all sentences are derived from one's ontological commitments. Even though this is logically sound, it is nonetheless linguistically irrelevant to pursue presuppositions that cannot be formally defined in terms of the immediate context. One way to attack this problem is to avoid it. The notion of completeness is restricted to completeness in formal characterization. For instance, pronouns may be regarded as constituting a formal category or a closed class of lexical items which can participate in sentence generation regardless of their referents. One can say then the 'derived' sentence mentioned above is grammatically complete though in want of additional information from the context in order to be completely meaningful.

Another way of looking at the problem is to assume that for each so-called 'derived' sentence there is an underlying form which is both syntactically and semantically complete, and that, through transformational processes that trim off redundant elements, it has lost its autonomy and become dependent on the context. Redundancy of form and meaning, therefore, can be attributed to as being the distributional constraint that operates beyond the boundaries of an otherwise 'autonomous' sentence. By the same token, a so-called 'elliptical' sentence can also be said to result from the application of transformations that trim off redundancies occurring both in the underlying form and the previous linguistic context. The natural consequence is that the trimmed sentence becomes apparently dependent on the context for a completeness in both meaning and form. For example, the utterance *John's.* occurring after the question *Whose car are you going in?* can be said to have structurally derived from a longer utterance *We are going in John's car.* through elliptical transformations.

According to Y. R. Chao (1968), the category of sentences is subdivided into 'full' and 'minor' sentences. The category of minor sentences includes those utterances which can be understood only in terms of 'external' elements in their linguistic and/or situational context. Corresponding to each minor sentence is a full sentence to which the minor sentence can be expanded and by which the minor sentence can be paraphrased. In order to account for these minor sentences which constitute a good portion[2] of our everyday speech, we must take into account the anaphoric or elliptical transformations and the 'external' structural and situational elements which motivate and condition the application of these transformations. It seems that within this theoretical framework the underlying form is always richer and more uniform in structure and has a claim to universality such that there is a built-in explanatory power for semantic interpretation and disambiguation while the surface form obtained after the application of transformations tends to obscure meaning, collapse structures, and may even result in ambiguity. It would seem that the theory contains an ideal structure which is degenerated in actual speech events. Thus we come to the conclusion that sentences are independent only by their very definition within the theory and their in actual practice sentence boundaries are crossed over and sentences are no longer self-sufficient.

We may even raise the question whether sentences are truly self-sufficient in the base component. In view of processes such as conjoining, embedding, pronominalization, and ellipsis related to the 'elliptical' or 'minor' sentences mentioned above, we know that the general practice has been such that wherever structural or semantic informations are lacking in the surface data 'dummies' or 'fillers' are used to fill in the gap between what is ideal and what actually occurs. It would be interesting to ask where and how do we get the information which requires the use of dummies. It is begging the question to provide the dummies first on the basis of semantic considerations and then claim syntactic autonomy on the basis of these 'dummified' structures. Even Chomsky's later proposal (1968) concerning 'intended referent' and the use of 'index' does not seem to have escaped this circularity.

The interpretation of an utterance would then be dependent on its derivational history with the P-marker and derived P-markers as well as the transformational rules involved on one hand and on the supplied indices for the intended referents, if any, on the other. It seems to me that structural indices are actually constraints on transformational operations. In other words, if the introduction of structural indices are semantically motivated, then by the simple law of transitivity the application of transformational rules are also semantically motivated in the cases concerned. It would be sheer ostrich-like obstinacy for a structuralist to refuse to see that the assumed sentence autonomy and syntactic autonomy are only smoke-screens created to protect himself from confronting the nebulous areas of discourse analysis and semantics.

Here I tend to agree with Fillmore that it is doubtful whether there is a 'level' of syntactic description discoverable one language at a time on the basis of purely syntactic criteria. In the following discussion in favor of question-words in the base component I am braving the criticism that was directed before toward Fillmore's case grammar (1965, 1968) that it is too strongly motivated by semantic considerations. I only hope that this would reveal certain linguistic universals in semantics.

2. Constraints on transformations.

As I was saying, sentences depend on their derivational history for their interpretation. The derivational history of a sentence consists of a P-marker, a derived P-marker, and relevant transformational rules and their order of application. It is commonly held that transformational rules can either be obligatory or optional. Within the system of partially ordered transformational rules an 'optional' transformation can either be by-passed or taken up as its turn comes.

By allowing optionality for transformational rules it is assumed that there are synonymous alternations by which we can express the same idea. This kind of alternation is generally known as stylistic variation. To borrow an expression from phonology, stylistic variations are considered 'free variations' since the change in form is not accompanied by a change in meaning.

However, it is also assumed for all transformations, optional or obligatory, that no change of meaning occurs after transformational operations. Does it follow that the transition from the base form to the surface form is also a matter of stylistic variation? The answer is 'Yes'. It is precisely a matter of stylistic variation that determines interlanguage differences. Whatever interlanguage that are observed can be construed as reflections of the universal semantic deep structure. Obligatory transformations, we may say, are obligatory only when we consider one language at a time. A transformation necessary to derive the surface form in language A may not be required in language B. Within a language, it follows, the set of obligatory transformations is sufficient to characterize its basic structures as contrasted with those of another language. Together with the base component obligatory transformations form the core of a grammar. As for 'optional' transformations within a language, it should be understood as the freedom to choose from two or more competing structures. During the derivational process one must make the choice, and once the choice is made, the transformational rule must be applied.

Hence, the dichotomy of 'obligatory' and 'optional' transformations is is not real and the terminology is quite misleading. It seems to imply that structures generated by obligatory transformations are more basic than those generated by optional transformations. The idea of a kernel sentence which assumes one of the several alternations to be more basic than the others is no longer held by Chomsky though he still stresses the importance of structural relatedness in the Aspects of the Theory of

Syntax (1965). Moreover, Fillmore's case grammar has successfully demonstrated that the so-called 'active' voice is not any more basic than the 'passive'. 'Subject' is interpreted as an aspect of the surface structure whereas in the deep structure we only have 'case' relations. A case relation and the NP-complement holding such relationship with the verb may get focused upon and become structurally marked as the subject of a sentence. This can be likened to the figure against the ground. This process of bringing out the figure we shall call subjectivalization or topicalization. Theoretically, all case relations have an equal chance, semantically if not statistically, of being focused upon and cast as the subject of a sentence. We are obliged to choose among these possibilities and hence their corresponding forms when we are producing an utterance. It is to be stressed that the keyword here is not 'optionality'; rather, it is 'selection'.

We may ask a related question whether these candidates for selection are indeed synonymous alternations? From my knowledge of the use of 'passive' forms in Chinese, English, and Japanese --to name just three common languages relevant to this issue, the passive structure seems to carry with it some connotations not conveyed by the active form. For example, the passive marker *bèi* and its variants *gěi* and *ái* of Mandarin Chinese always co-occurs with verbs which imply undesirable consequences. In Chinese we would say *Ta ái dǎ le.* 'He was beaten up.' but not **Ta ái shǎng le.* 'He was given a reward.' Similarly, English 'get' co-occurs with a class of verbs implying adversity or undesirable events as in 'get killed', 'get blamed', 'get fired', 'get broken', etc. (It was suggested during one of the meetings of our Generative Grammar Discussion Group at the University of Hawaii that 'get married' also belongs to this category) As for passive forms in Japanese, they convey the feeling of submissiveness, passivity, and even an intended evasion of responsibility. In a report given by A. Miyakawa-Howard (1968) The Japanese passive is an adversitive passive. When a person is making the statement that *X ga kita* 'X visited me.' he may be neutral or favorable to X's visit, but when he says *X ni korareta* 'I was visited by X.' he means that X's visit is not welcomed. When combined with the causative, the passive seems to indicate complete passivity and freedom from responsibility. This is well illustrated by the frequent expression used by husbands going home late to their wives: *nomasareta* 'I was made to drink.'

To return to case grammar which has incorporated the choice of 'active' and 'passive' in the base component, it is hard to believe that an agent-focused sentence has exactly the same meaning as its object-focused counterpart or its instrument-focused counterpart. One may argue that focusing is only a matter of attention shifting, a difference in the degree of emphasis. However, a shift of attention often reduces the background. As a result, the distribution of information becomes essentially different. The bits of information carried by these 'synonymous' sentences do not match one another. This can be shown by the results of anaphoric processes. The portion of a sentence not in focus may be partially or wholly deleted but not the portion in focus. This implies that once a certain figure is cast in focus the ground sort of fades, and that the deletable portion of information is not as essential as the focused portion. The structural configuration is different; the Gestalt is different; the information conveyed and eventually the perceived meaning is different. If we would like to stick to the claim that transformations do not affect meaning, then we would have to incorporate focus and emphasis into the base component just like what is done with negation. It is the transformational operator NEG that carries the meaning of negation and not the surface forms, say 'not' and the auxiliary 'do' in English. Lexical meanings of these words are only to facilitate lexical insertion and they have nothing to add to the semantic interpretation already carried by the function-word NEG. Hence it is only a transition of form without change of meaning that is involved when lexical items are introduced. In this theory we are more concerned with formal, structural semantic interpretation of utterances in terms of function and categories than with the membership of these functional or categorial classes.

Still we have the problem of selection and transformational constraints to deal with. If we are to completely eliminate 'optional' transformation and place the burden of selection of alternative structures on the base component, we would like to know how one of the several possible transformational operators is chosen. Are sentences randomly genreated out of all the possible combinations of syntactic categories and transformations? Or are there statable reasons for making one choice rather than the others? Obviously there are situational motivations. The production or perception of sentences involve at least two parameters, namely, the structural parameter and the situational parameter. One may wish to add a statistical parameter since some forms are indeed 'favored' and have higher frequency of occurrence. For example, given the choice of agent-focus and object-focus constructions, Chinese favors the former and uses the latter only with a sense of adversity and undesirability, whereas in Amis and Tagalog object-focused constructions are more frequently use and do not limit themselves to verbs implying undesirable consequences. Nominalization of verbs is very frequently used in Amis. Utterances like $\underset{1}{\text{ira tukur}}$ ‖ ku $\underset{2}{\text{sapaj}}$-$\underset{3}{\text{ala}}$ $\underset{4}{\text{nira}}$ tandaw $\underset{5}{\text{tia nani}}$ '$\underset{1}{\text{The ladder}}$ is what $\underset{4}{\text{the man}}$ $\underset{2}{\text{uses}}$ $\underset{3}{\text{to rescue}}$ $\underset{5}{\text{the cat}}$.' constitute approximately 30% of Amis sentences involving verbal constructions. Indeed such constructions are structurally similar to equational constructions involving two NP's like u $\underset{1}{\text{ina}}$ $\underset{2}{\text{aku}}$ ‖ $\underset{3}{\text{kina}}$ $\underset{4}{\text{matu asaj}}$ '$\underset{3}{\text{This}}$ $\underset{4}{\text{elderly person}}$ is $\underset{2}{\text{my}}$ $\underset{1}{\text{mother}}$.' That sapaj-ala is an NP is marked by ku, the article used to introduce a focused NP. In English gerunds or verbal nouns are used much less frequently than in Amis. In Chinese such constructions are not used at all. A word-for-word translation of the English gerundial expression such as 'his leaving' *ta dè lí-kai or 'my typing' *wǒ dè dǎ-zì are terribly awkward if not unacceptible expressions. How we can express this sort of linguistic favoritism of individual languages in our present theory is beyond the scope of the present paper. Now let us return to an examination of the structural and situational parameters.

Structural constraints on transformations are given in the form of 'structural description' (SD) of the input to the transformational rule, but this device is quite inadequate. For instance, it is incapable of expressing structural relatedness and redundancy which is the primary motivation for processes like embedding, pronominalization, and deletion. Eventually labeled bracketing and indices are used. Conditions under which the transformation does not apply are simply listed after the structural description of the input tree. For the purpose of illustration, I shall cite Ross' statement of the conditions for pronominalization:

Given the following SD:

$$\begin{array}{ccccccccccc} X & - & \begin{bmatrix} \text{NP} \\ -\text{PRO} \end{bmatrix} & - & Y & - & \begin{bmatrix} \text{NP} \\ -\text{PRO} \end{bmatrix} & - & Z & \qquad & \text{OBLIG} \\ 1 & & 2 & & 3 & & 4 & & 5 & & \Longrightarrow \end{array}$$

$$\text{A.} \quad 1 \quad 2 \quad 3 \quad \begin{bmatrix} 4 \\ +\text{PRO} \end{bmatrix} \quad 5 \qquad\qquad \underline{\text{or}}$$

$$\text{B.} \quad 1 \quad \begin{bmatrix} 2 \\ +\text{PRO} \end{bmatrix} \quad 3 \quad 4 \quad 5$$

The following conditions apply:

(i) 2 = 4

(ii) That the structural change in A. is subject to no conditions

(iii) That backward pronominalization is only permissable if the NP in term 2 is a part of the subordinate clause which does not contain the NP in term 4.

This presentation, accurate as it may be, is far from being elegant. What is happening is that when efforts are made to simplify the base component the transformational system inevitably has to become more complicated to accomodate the varied surface structures. Assuming a universal semantic base component to be desirable, our task is to improve on the present convention for expressing transformational constraints. This is indeed no easy task and should be the subject of further studies comparable in size and scope to Ross' Ph.D. Dissertation on constraints on variables.

Our concern here is the situational parameter which is the most difficult to trace in structural terms. In order to incorporate linguistic and situational contexts for actual connected discourse, the problem of presuppositions is raised. If we are to imitate communication in action, our model should be able to indicate a chain of stimuli and responses. The grammatical device should have a memory to hold the previous linguistic context as well as some vital information of the persons and situation involved. During a communicative process the memory is constantly scanned to find gaps in information which would motivate the next speech act. There seems to be no upper limit to the memory as the subjects we can talk about are open-ended. However, we may limit ourselves to one subject-matter at a time and consider only the immediate context.

We can then scan our relatively small memory and see what further information can be given or asked for. I propose to build the memory just the same way as the base component. The cells in the base component are matched one by one with the information stored in the corresponding cells in the memory. When a gap is found, we try to supply the information. The gaps of information would be represented by the presence of question-words in the cells. We shall see in the following discussion that a stimulus-response model as proposed here is not only commonsensical but that it helps to dissolve certain problems concerning reference and presuppositions.

3. Question-words in the Base Component.

In the use of language it is clear that an explicit question in the conversation would condition the content and structure of the answer. The forms of the questions are well-defined. In Chinese, a 'yes-no' question has the form *A-not-A* while question-words like *shéi* 'who', *shénmè* 'what', *gèi shéi* 'by whom' should be able to get us the desired focused structures for our answers. When anaphoric processes are applied, the part directly responding to the question-word is generally preserved. There are also question-words or expressions which would elicit as their responses sentences with verbal constructions. Examples are: *zuò shénmé* 'What does X do', *shénmè shì* 'What is going on?' or 'What happened?'

The base component of a grammar is actually a system of question-words. We have question-words to replace all the major categories and constituents, By the use of various question-words grammatical functions of these constituents can also be expressed. A logical way to use the language in connected discourse is to scan the memory and find the piece of information we want to elaborate upon or a gap in information that we want to fill. In the former case redundancies exist and we have the motivations to delete part of the information. In the latter case the gap receives special attention and serves as the motivation for topicalization and emphasis. Sometimes two or more gaps may be unfilled and may even suface with the question-words in them. Consider Ross' example:

Who is buried where is unknown.

Ross finds it difficult to state exactly what are the origins of this particular sentence. He probably has in mind sentence-conjoining in the form of 'respectively'. In our scheme it would be very simple to give the origin such a sentence. The two cells and their interrelations are the information gap that we are trying to fill.

In the next workshop I shall work out in detail the use of question-words in sentence generation and the constraints they impose on the rules of transformation.

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COMPUTING AND CASE GRAMMAR

or

Remarks on the attempted application of a computer program for Aspects to an attempted lexicalist-case grammar for English

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1. Introduction

In this paper we are concerned with the attempted application of a computer model of transformational grammar (based on Aspects) to a grammar based in part on more recent theories, in particular the lexicalist and case theories. The computer system is one written at Stanford a few years ago and described in the CACM, June 1969, and Friedman et al. (forthcoming). The grammar is the UCLA English Syntax Project grammar, written primarily by Stockwell, Schachter and Partee and described in a two-volume unpublished report and, we understand, some forthcoming publications.

The main part of the paper describes our attempt to mesh these two projects. First, it may be in order to comment on why this seemed to be an interesting thing to do.

a. Historical background

The design and programming of our computer system for transformational grammar was carried out, at Stanford, in the two years September 1966 - August 1968. At UCLA, for a period slightly longer at both ends, the same sponsor (The Air Force Electronic Systems Division) supported the project on the Integration of Transformational Theories on English Syntax. One idea in having the two concurrent projects was that the linguistics project would write a grammar, and that our Computer Science project would construct some programs which would be in some way useful as aids to the linguistics project (and hence, to other projects in which grammars were being written).

As it turned out, there was some interaction between the two projects. We exchanged memoranda and working papers, and in the spring of 1968, when our programs were essentially complete, one of the members of the UCLA group came up on two occasions and ran some simple grammars. These grammars were small and preliminary, and while they embodied some of the ideas which were to be the basis of the final version, they were not convincing evidence that we could in fact accept the kinds of grammars we had set out to work with.

Notice that there is an obvious problem in writing computer programs to accept grammars -- that is, the notion of what a grammar is can change more rapidly than computer programs can be written. A good recent example of this occurs in Joan Bresnan's paper [1]; if her elegant argument about the nuclear stress rule in phonology in fact influences the way in which people write phonological rules, then of the current phonological rule- and grammar-tester programs, those which do not also handle syntax are immediately unable to treat stress, and those which currently handle syntax and phonology in serial may be subject to major revision. This will depend of course on the details of the particular program -- the Bresnan suggestion might, in some possible worlds, be handled with no program changes.[1] In view of this history, it is not unnatural to be curious about whether the final UCLA grammar could be accepted by our programs.

Another reason for the attempt to translate and run the UCLA grammar is that it is the largest formal transformational grammar of English available. This immediately makes it important, and would justify trying to put it into computer form. The computer form makes it much more accessible for purposes of teaching and experimentation.

So much for reasons for wanting to try to put the UCLA grammar into our computer system. I will now describe very briefly the form of the UCLA grammar, and then give a quick sketch of what a computer system for grammar looks like. Then I will discuss in detail two specific aspects of the computer system which directly affect the way we implemented the UCLA grammar.

---

[1] We intend to investigate the question of which of the possible worlds is the actual one for our grammar-system and hope to be able to comment on this in November.

b. The UCLA grammar

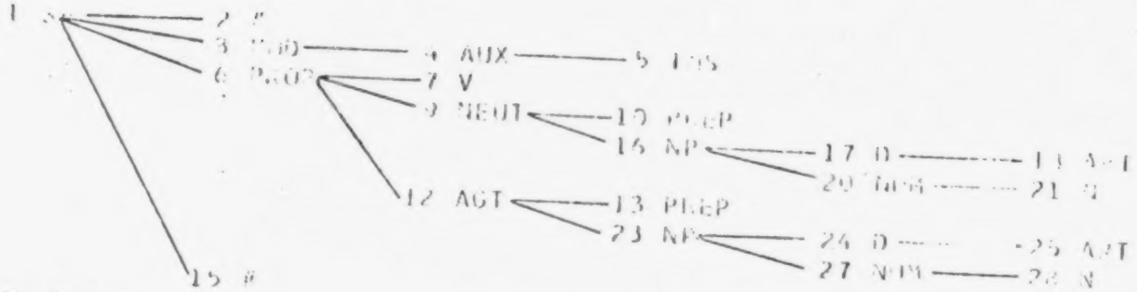
The UCLA grammar [6] is a large (62 transformations), relatively formal grammar, accompanied by a two-volume defense. It draws linguistic insights from a variety of sources and unifies them by presentation in a lexicalist-case framework. It is not the purpose of this paper to comment on the adequacy of the grammar as a grammar of English, nor to criticize it in any way.[1] We take the grammar as given, and use it as an example in an investigation of how to represent case.

As a brief introduction to the UCLA grammar, we give a short sample derivation. The derivation begins by phrase structure generation of the tree[2] of Figure 1.

---

[1] For a critical study of parts of the UCLA grammar, see Friedman and Myslenski [M-11].

[2] In the tree representation used throughout this paper, daughters of a node are written to the right with left-most daughters in the highest position. Numbers indicate internal node numbers in the computer representation.

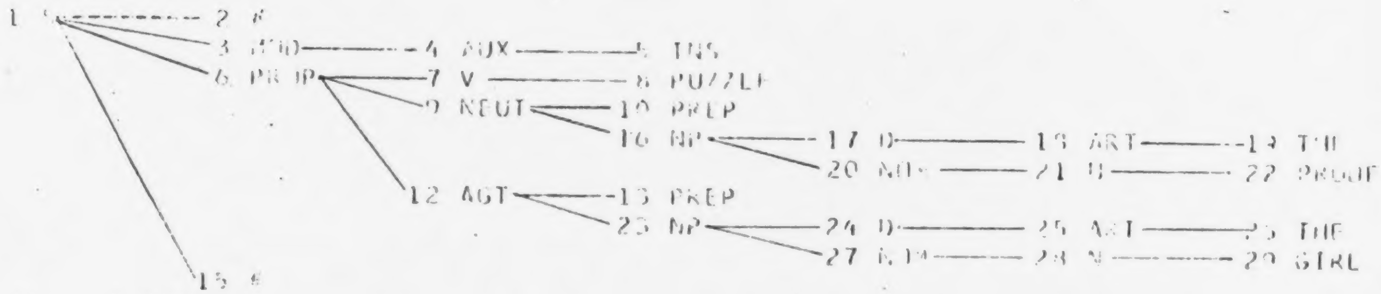

1 S
2 #
3 MOD
4 AUX
5 TNS
6 PROP
7 V
9 NEUT
10 PREP
16 NP
17 D
18 ART
20 NOM
21 N
12 AGT
13 PREP
23 NP
24 D
25 ART
27 NOM
28 N
15 #

```
NODE 5 TNS
    [-PAST]
NODE 10 PREP
    [+NEUT]
NODE 16 NP
    [+NEUT]
NODE 13 PREP
    [+AGT]
NODE 23 NP
    [+AGT]
```

Figure 1

Points to notice about the base tree are first the case structure, and second the somewhat unusual generation of feature specifications in the phrase structure component.

After lexical insertion, with verbs inserted before nouns, a possible result for this base tree is:


1 S
2 #
3 MOD
4 AUX
5 TNS
6 PROP
7 V
8 PUZZLE
9 NEUT
10 PREP
16 NP
17 D
18 ART
19 THE
20 NOM
21 N
22 PROOF
12 AGT
13 PREP
23 NP
24 D
25 ART
26 THE
27 NOM
28 N
29 GIRL
15 #

```
NODE    5 TNS
          |-PAST|
NODE    7 V
          |+V -ADJ|
NODE    9 NEUT
          |+NEUT|
NODE   10 PREP
          |+NEUT|
NODE   18 ART
          |+ART -PRO -DEM|
NODE   21 N
          |+N -ANIMATE -ABSTRACT +COUNT +COMMON -FACT -IMPER [illegible]|
NODE   12 AGT
          |+AGT|
NODE   25 ART
          |+ART -PRO -DEM|
NODE   28 N
          |+N +HUMAN +ANIMATE -ABSTRACT +COUNT +COMMON -MASC|

          # TNS PUZZLE PREP THE PROOF PREP THE GIRL #
```

Figure 2

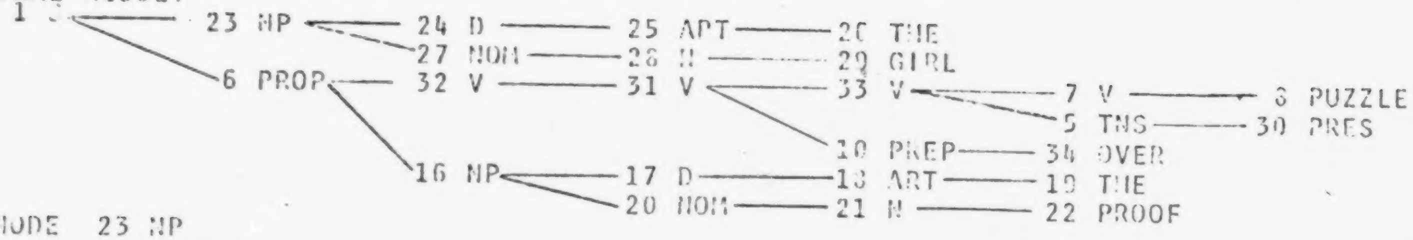
The first transformation which applies to this tree is PREP-SPREAD, which moves the preposition over onto the first preposition from the complex-symbol of the V dominating puzzle (that feature is not shown in the tree above because, as we shall see later, in the computer system it was implemented differently).

The case placement transformations then apply. UOBJ (Unmarked Object) selects the proof as the object and adjoins it as right sister of the verb puzzle. The corresponding preposition over is chomsky-adjoined to the right of puzzle. ACTSUBJ (Active Subject) selects the girl as subject and adjoins it as left sister of MOD. The corresponding preposition (node 13) is erased.

The final step in completing the derivation is AFFIXSHF (Affix Shift), which chomsky-adjoins the tense marker to the verb.

The resulting tree is given below. Its terminal string is The girl puzzle PRES over the proof.

FINAL RESULT


1 S
23 NP
24 D
25 ART
26 THE
27 NOM
28 N
29 GIRL
6 PROP
32 V
31 V
33 V
7 V
8 PUZZLE
5 TNS
30 PRES
10 PREP
34 OVER
16 NP
17 D
18 ART
19 THE
20 NOM
21 N
22 PROOF

```
NODE  23 NP
         |+AGT|
NODE  25 ART
         |+ART -PRO -DEM|
NODE  28 N
         |+N +HUMAN +ANIMATE -ABSTRACT +COUNT +COMMON -MASC|
NODE  32 V
         |+V -ADJ|
NODE  31 V
         |+V -ADJ|
NODE  33 V
         |+V -ADJ|
NODE   7 V
         |+V -ADJ|
NODE   5 TNS
         |+TNS -PAST|
NODE  10 PREP
         |+PREP +NEUT|
NODE  16 NP
         |+NEUT|
NODE  18 ART
         |+ART -PRO -DEM|
NODE  21 N
         |+N -ANIMATE -ABSTRACT +COUNT +COMMON -FACT -IMPER -WHS|

         THE GIRL PUZZLE PRES OVER THE PROOF
```

Figure 3

c. The computer system and its use

We have treated the UCLA grammar within a computer system designed to accept transformational grammars and to generate sentences according to the rules of the grammar. The computer program runs on several different computers, including both IBM and CDC machines. The user of the program prepares a computer readable version of a grammar, according to specifications provided. He also provides as input to the program information about the types of output which he wants. He may ask to see completely random trees, or, at the other extreme, to see the result of transforming a particular base tree which is already provided with its lexical items. Within this wide range, the system makes it possible for the user to obtain trees which relate to any particular aspect of the grammar of his current concern, be it a particular transformation, or a particular lexical construct. The user also specifies to the program the amount of output desired, both the number of runs for each input specification and the amount of intermediate output in a derivation.

The program assists the linguist by providing examples of derivations within the grammar. It is not an exhaustive tester, nor are probabilities attached to the rules.

The system is definitely not intended to be used for evaluation of a grammar written by someone else; it is meant to help the writer of a grammar. In completing the formalization of a grammar to the point where it is comprehensible to a computer program, there are inevitable decisions which will affect how the grammar works, so that it is no longer entirely the responsibility of its original authors. The translation process, if done independently of the authors, may well distort their intentions -- (For example, there is more than one interpretation of the instruction "Attach node 2 to node 4" -- is this as sister, daughter, and so forth).

Examination of computer-generated derivations is bound to turn up problems both in individual transformations and in interactions of rules. The similarity between a large grammar and a large computer program suggests that it is unlikely that a consistent grammar can be written (particularly with more than one author) without extensive computer testing. (We computer programmers can't do it -- how could they be able to?) There will be bugs. It is reasonable only to ask whether the bugs can be repaired without doing violence to the structure of the grammar -- to ask that a grammar be initially bug-free is asking far too much.

2. The Computer Model

We turn now to a more detailed examination of the model which underlies the computer program. After some brief comments on the model as a whole, we will examine the process of lexical insertion and the use of n-ary features in the phonological component. Once these two aspects of the model are understood, it will be easy to see how the case grammar was implemented.

The model includes lexical insertion, phrase structure generation, and transformation. The computer model is based on *an interpretation of* the model in Chomsky's *Aspects*. However, it does not follow Chomsky in all his decisions. In a number of cases we have offered broader alternatives, and allowed the user to agree with Chomsky as one possible choice.

An example of this freedom is in the order of lexical insertion. We did not want to turn away users who want to insert verbs first, and serve only noun-first linguists. . . indeed, it seemed that one might want to be able to try either alternative. So we require the user to specify as an input to the program (that is, as part of the grammar) the order of lexical insertion. He can agree with Chomsky if he likes. (Actually, it is hard to construct an example where it matters.)

A recent major modification to the model is its extension to include a phonological component, based in part on the system given in Chomsky and Halle's Sound Pattern. The program changes needed for phonology n-ary features and variables over feature values were extremely convenient in our translation of the UCLA grammar.

a. Lexical insertion

After the generation of a phrase structure tree, the next step in the generative process is the insertion of lexical items into the tree. Each lexical item is characterized by various unanalyzable explicit features and also by contextual features, which are analyzable as structural descriptions. These structural descriptions are matched against the tree to determine if the lexical item is suitable for insertion at a particular point. If so, certain side effects of the insertion, indicated by the contextual feature, are performed as the item is inserted.

To illustrate the use of contextual features, we give as Figure 4 a simple lexical component. The illustration, which is not to be taken too seriously, shows how inserting a verb such as drink, which requires a liquid object, constrains the

```
        "ILLUSTRATION OF LEXICAL COMPONENT"
PHRASESTRUCTURE
     S = # NP VP # .
     VP = V (NP) .
     NP = (DET) N .
     $ENDPSG
LEXICON
     CATEGORY  V  N  DET .
       INHERENT
          ABSTRACT  ANIMATE  COUNT  HUMAN  LIQUID .
       CONTEXTUAL
          V1 = <VP/< _ % N|+LIQUID|>>,
          V2 = <VP/< _ % N|-LIQUID|>>,
          TRANS = <VP< _ NP >>,
          COMMON = <NP< DET _ >>,
          ANIMSUBJ = <S<# NP<% N|+ANIMATE|> VP<_ %>#>>,
          NANIMSUBJ = <S<# NP<% N|+ANIMATE|> VP<_ %>#>>,
          ANIMOBJ = <VP< _ NP<% N|+ANIMATE|>>>,
          NANIMOBJ = <VP< _ NP<% N|-ANIMATE|>>>,
          NABSTOBJ = <VP< _ NP<% N|-ABSTRACT|>>> .
      RULES
          |+COUNT|  =>  |+COMMON|,
          |+ABSTRACT|  =>  |+COMMON -ANIMATE|,
          |+HUMAN|  =>  |+ANIMATE|,
          |+LIQUID|  =>  |-ANIMATE -ABSTRACT|>>>,
          |+ANIMATE|  =>  |-ABSTRACT| .
      ENTRIES
          SINCERITY VIRTUE  |+N -COUNT +ABSTRACT|
          BOY  |+N +COUNT +HUMAN|
          GEORGE BILL  |+N -COMMON -COUNT +HUMAN|
          THE |+DET|
          EAT  |+V +V2 +TRANS +ANIMSUBJ +NABSTOBJ|
               |+V -TRANS +ANIMSUBJ|
          FRIGHTEN  |+V +TRANS +ANIMOBJ|
          BOOK  |+N -LIQUID -ANIMATE +COUNT|
          STUFF  |+N +COMMON|
          BEER  |+N +COMMON +LIQUID|
          DRINK  |+V +V1 +ANIMSUBJ|
          BREAK  |+V +V2 +ANIMSUBJ +NANIMOBJ +NABSTOBJ|
          .
     $ENDLEX
```

Figure 4

later[1] selection of the object noun to one which is not marked -LIQUID, while selection of break constrains the object to one which is not marked +LIQUID. At the same time the object noun takes the appropriate value of the feature LIQUID. In Figure 6 we show the complex symbols associated with the object noun after lexical insertion is complete. The example uses the vague noun stuff, which is marked in the lexicon as +N and +COMMON only. The underlying phrase structure for the sentence is

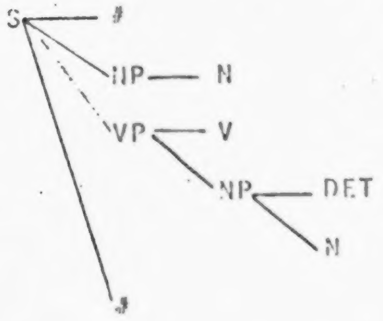


Figure 5

---

[1] One of the consequences of this model of lexical insertion is that the class of possible sentences is independent of the order of insertion of V and N. We insert verbs first because it is more efficient to do so.

In sentence (1), the verb *drink* is selected. *Drink* is marked in the lexicon as |+V +V1 +ANIMSUBJ|. V1 and ANIMSUBJ are both contextual features. The definition of the first of these is V1 = ⟨ VP/ ⟨_ N|+LIQUID|⟩. It specifies that a word with this feature must be inserted only in a VP, where it must immediately precede an N which is compatible with the feature +LIQUID. Since the verb is inserted before the noun, the feature +LIQUID is added to the otherwise initially empty complex symbol for the N, as a side-effect of inserting the verb *drink*. The feature +LIQUID is added at the time *drink* is inserted, and will thus force the subsequent choice of a noun to be compatible with the feature +LIQUID. (Had a noun already been present, say by being specified on input, the selection of drink would be possible only if the noun were compatible with +LIQUID.) Once the feature specification +LIQUID is inserted, the specifications -ANIMATE and -ABSTRACT follow automatically by a redundancy rule in the lexicon. Insertion of the verb drink also has a side-effect on the subject noun: the contextual feature specification +ANIMSUBJ forces the subject noun to be +ANIMATE.

In contrast to sentence (1), sentences (2) and (3) give different sets of features for the object stuff.

Figure 6

COMPLEX SYMBOLS AFTER LEXICAL INSERTION

(1) GEORGE DRINKS THE STUFF

|+N -ABSTRACT -ANIMATE +LIQUID +COMMON|

(2) BILL BREAKS THE STUFF

|+N -ABSTRACT -ANIMATE -LIQUID +COMMON|

(3) GEORGE FRIGHTENS THE STUFF

|+N -ABSTRACT +ANIMATE +COMMON|

The use of contextual features and side-effects suggests itself as a way of handling prepositions in case grammar without a PREP-SPREAD transformation and without adding any new mechanism to the system. Just as drink marks its subject as +ANIMATE and its object as +LIQUID, so might a verb, say rely, mark its neutral preposition with a feature selecting uniquely the preposition on.

b. Features in phonology

The fact that there is a small number of cases immediately suggests that case be treated as an n-ary feature, like stress in phonology. In the UCLA grammar there are 7 different case features, +ESS, +DAT, . . . , +PART, and presumably also some implicit redundancy rules to guarantee that no node is marked for two different cases. An n-ary feature expresses just this situation: if CASE is an n-ary feature with 7 possible values, then, by very basic conventions, no node can be marked for two different cases, since that would be to have two values for the same feature.

As the treatment of the UCLA grammar developed, we found the n-ary features to be extremely valuable in this and other ways. To show how this came about we first describe the parts of the system which we used.

i) n-ary features

In the purely syntactic versions of our computer system, the values for features were only the two signs + and -, and the unspecified value (roughly ±) indicated by *. Phonology rules require the use of numerical feature values and of variables over those values. These are the "n-ary features" to which we refer. To handle n-ary features, the syntax of transformational grammar was modified,[1] so that (1) values may be either signs or integers, (2) there are variables over feature values, and (3) restrictions allow numerical comparisons of feature values.

Numerical values are most important for the stress rules. A good example of the notation of our system is the auxiliary reduction rule, here somewhat simplified:

```
TRANS  AUXRED  "AUXILIARY REDUCTION".
SD  %  1'|(ALPHA)STRESS| ('C) '|(BETA)STRESS| %,
    WHERE (ALPHA>BETA) & (BETA<4).
SC  |-STRESS|  MERGEF  1.
```

This rule applies whenever there are two stressed elements, possibly separated by a consonant ('C). If the stress value of the first is greater than that of the second, and the second is less than 4, then the first becomes unstressed.

---

[1] The new syntax rules for *value* are:

4.08 *value* ::= *sign* [] *integer* [] * [] - [] (*prefix*)

4.09 *prefix* ::= *sign-prefix* [] *integer-prefix*

4.10 *sign-prefix* ::= opt[-] *variable*

4.11 *integer-prefix* ::= *variable* opt[*sign* *integer*]

ii) variables over feature values

The AUXRED transformation illustrates also the use of variables over feature values. ALPHA and BETA are used as the variables. We see that they can be compared with one another and with integers. Simple arithmetic is also possible. For example, in one stress adjustment rule we find the change |(ALPHA+1)STRESS| MERGEF 2. This will add one to the value of ALPHA and then store the result as the STRESS value of node 2.[1]

iii) phonological abbreviations

The phonological component of a grammar contains a set of phoneme definitions. These phoneme definitions are used in printing a tree in which the phonemes are represented internally only in terms of features. The internal representation, needed for the phonological rules, is fully expanded. However, when a tree is printed out, only the abbreviation is seen. For example, the output form of the tree for courage displays for node 8 only the letter E with the feature specifications -TENSE, -STRESS which are not part of the complex symbol that E abbreviates.

---

[1] More precisely, the node corresponding to the term numbered 2 in the structural description of the rule.

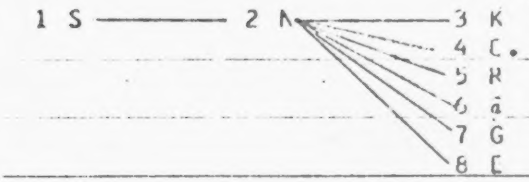
PHONEMES

```
  O. = |-CONS +VOC -HIGH +BACK -LOW -ANT +ROUND|,
  O, = |-CONS +VOC -HIGH +BACK +LOW -ANT +ROUND|,
  ə  = |-CONS +VOC -HIGH -BACK +LOW -ANT -ROUND|,
  Λ  = |-CONS +VOC -HIGH +BACK +LOW +ANT -ROUND|,
  E  = |-CONS +VOC -HIGH -BACK -LOW -ANT -ROUND|,
  UH = |-CONS +VOC -HIGH +BACK -LOW -ANT -ROUND|,
  EH = |-CONS +VOC -HIGH -BACK -LOW -ANT -ROUND|,
  R  = |+CONS +VOC -ANT +COR +VOICED -STRID +CONT|,
  S  = |+CONS -VOC +ANT +COR -VOICED +STRID +CONT|,
  J  = |+CONS -VOC -ANT +COR +VOICED +STRID -CONT|,
  K  = |+CONS -VOC -ANT -COR -VOICED -STRID -CONT|,
  G  = |+CONS -VOC -ANT -COR +VOICED -STRID -CONT|.
```

$END

Figure 7

Phoneme Definitions



```
        K O. R ə G E

4 O.    |-TENSE -STRESS|
6 ə     |-TENSE -STRESS|
7 G     |+DER|
8 E     |-TENSE -STRESS|
```

Figure 8

Output tree for <u>courage</u>

3. Application to Case Grammar

At this point we have sufficient background to explore the use of the aspects of the system described above to the representation of case grammar.

a. Case nodes and the CASE feature

Following UCLA, we introduce case nodes in the expansion of the nodes PROP and NOM; the rules are:

"4" PROP = V (ESS) (NEUT) (DAT) (LOC) (INS) (AGT) .

"7" NOM = (NOM (S), N (NEUT) (DAT) (LOC) (INS) (AGT)).

"5" ESS = PREP NP .

NEUT = PREP NP .

. . .

AGT = PREP NP .

The first representational problem arises with rule 5, which UCLA states not simply as above but as:

$$\text{ESS} \rightarrow \underset{[+\text{ESS}]}{\text{PREP}} \quad \underset{[+\text{ESS}]}{\text{NP}}$$

$$\text{NEUT} \rightarrow \underset{[+\text{NEUT}]}{\text{PREP}} \quad \underset{[+\text{NEUT}]}{\text{NP}}$$

. . .

This rule cannot be transformed directly into our phrasestructure notation. Instead, we introduce the contextual features VCASE and NCASE which will put case features on the case nodes, and the transformation FPLACE (which is the first transformation) which moves the case feature to PREP and NP appropriately. Thus in the list of inherent features, under n-ary features, we have a feature CASE . In the contextual definitions we define

VCASE = ⟨PROP ⟨_ (ESS|1CASE|)(NEUT|2CASE|) . . .
(AGT|6CASE|)⟩⟩

NCASE = ⟨NOM ⟨_ (ESS|1CASE|)(NEUT|2CASE|) . . .
(AGT|6CASE|)⟩⟩

and we add the redundancy rules

|+V| = |+VCASE|

|+N| = |+NCASE|

which will mark every verb for VCASE, at the time of lexical insertion. Consequently as soon as the verb has been inserted in the tree, the case nodes will contain the CASE feature with the correct value.

The CASE feature is moved onto PREP and NP by the transformation FPLACE:

```
"FEATURE TRANSFORMATION"

TRANS FPLACE I AACC .

SD % * |(ALPHA)CASE| ⟨1PREP 2NP⟩ %.

SC |(ALPHA)CASE| MERGEF 1, |(ALPHA)CASE| MERGEF 2 .
```

This transformation is the only one in group I and is applied throughout the base tree before any other transformations are applied. It matches an arbitrary node (*) which has a specification for the feature CASE and has the daughters PREP and NP. The structural change marks the PREP and NP with the same CASE specification as the parent node.

In the UCLA grammar the value of the feature CASE is represented as a subscript on C:

$$\text{S.I.}\quad X \quad \underset{+C_j \rightarrow \text{OBJ}}{\begin{Bmatrix} V \\ N \end{Bmatrix}} \quad {}_{C_i}[\text{PREP NP}] \quad X \quad {}_{C_j}[\text{PREP NP}] \quad X \qquad \text{(page 864)}$$

The CASE feature would allow us to state this structural description as

```
SD % * |(ALPHA)OBJ| * |(GAMMA)CASE| ⟨PREP NP⟩ %
        * |(ALPHA)CASE| ⟨PREP NP⟩ %.
```

b. N-ary features for object and subject selection

The SD above also illustrates the n-ary feature OBJ which selects the correct case for Object (an n-ary feature SUBJ also exists). The feature specification written by UCLA as $+C_j \rightarrow \text{OBJ}$ is for us the feature specification *j*OBJ, where *j* is an integer. (This appears to be a true n-ary feature because UCLA never uses $-C_j \rightarrow \text{OBJ}$.)

In the LEXICON entries are marked for OBJ and SUBJ. For example, *accuse*, which makes DATIVE the object, is 3OBJ; *contain*, which takes locative subject, is 4SUBJ.

c. Features for prepositions

As we interpret the UCLA grammar, there are four distinguishable types of occurrences of prepositions. Certain occurrences (1) are "real" and "meaning-bearing". These are selected from the lexicon. Other occurrences (2) are predictable from the verb and case. For example, *laugh* takes *at* for the NEUT case, and *puzzle* takes *over* for NEUT. Some occurrences (3) of *of*, *for* and *by* are inserted by transformations (other than PREP-SPREAD). Finally, other occurrences (4) are predictable from CASE alone, unless the default choice has been overridden earlier in the derivation.

In the UCLA grammar a transformation PREP-SPREAD inserts the prepositions in the second group above. It is argued that PREP-SPREAD must occur after GERNFACT (gerundive, non-factive) because type (2) prepositions must not be selected by that rule. We have restated GERNFACT to distinguish between "real" and other prepositions, and thus do not need PREP-SPREAD. The choice of preposition for a particular case can be stated as part of the case frame feature, and the PREP will at lexical insertion time be marked with the correct specification *i* PRP. For example, *laugh* has the contextual feature + ⟨PROP ⟨_ (NEUT ⟨PREP|1PRP|%⟩)AGT⟩⟩. This specifies that its case frame requires an AGT and may optionally contain a NEUT. If it contains a NEUT, the corresponding PREP will be marked 1PRP.[1]

The n-ary feature PRP has one value for each word which can occur as a preposition of type (2), (3) or (4) above. In the course of a derivation, prepositions (2) and (3) do not explicitly appear as terminal symbols but are carred as the PRP feature on PREP.

---

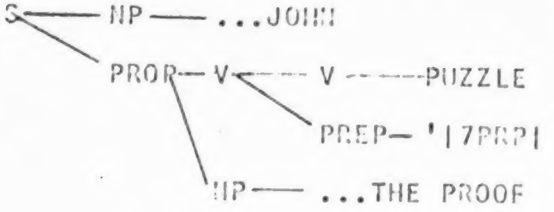
[1] In discussion of an earlier version of this paper, David Bennett pointed out that this view of prepositions may be somewhat simplistic, as there seems to be a continuum from verbs which take only one NEUT preposition (*rely on*), to verbs which have a small class of possibilities (*laugh at*, *laugh over*), to verbs which are free to take any "real" preposition. Several possibilities suggest themselves as solutions to this problem: one might provide several complex symbols for *laugh*, each with a different preposition selection. Or, one might use a feature, say DURATIVE, to distinguish between the two, assigning *laugh* the specification *DURATIVE in the lexicon, so that the system will select either + or - at the time of lexical insertion, and including redundancy rules which imply that if *laugh* is +DURATIVE, *over* is selected, if -DURATIVE then *at* is selected.

A final transformation PREPINS creates corresponding terminal nodes for PREP's which remain. If PRP occurs (type (2) or (3)), its value determines the preposition; otherwise (type (4)) the value of the CASE feature decides.

```
PHONLEXICON
  PHON
     AT     =  |1PRP|,
     OF     =  |2PRP|,
     TO     =  |3PRP|,
     FROM   =  |4PRP|,
     WITH   =  |5PRP|,
     BY     =  |6PRP|,
     OVER   =  |7PRP|
$ENDPHON
```

```
"POST-CYCLIC TRANSFORMATIONS"
     TRANS PREPINS V OB AACC .
         SD % 1PREP %, WHERE TRM 1.
         SC IF < 1 INC1 |(ALPHA)PRP| >
            THEN < ('|(ALPHA)PRP|) AFIDE 1 >
            ELSE < IF < 1 INC1 |(BETA)CASE| >
                     THEN < (' |(BETA)PRP|) AFIDE 1 >>.
```

After PREPINS the terminal preposition nodes have the feature PRP but do not have the decoding of it as an actual preposition. But this is supplied from the PHONLEXICON by the same process as that which supplies letters in place of phonological complex symbols. Thus the tree may remain


S
NP
...JOHN
PROP
V
V
PUZZLE
PREP
'[7PRP]
NP
...THE PROOF

but whenever it or the corresponding sentence is printed, over is substituted for [7PRP], by a decoding from the PHONLEXICON.

4. Representation of Lexicalist Theory

The UCLA grammar is a lexicalist-case grammar. We have discussed our implementation of the grammar in the computer system from the point-of-view of *case*. It remains to discuss the formal implications of the lexicalist hypothesis. Here, in contrast to case, we did not really make a serious attempt to capture the lexicalist aspects of the grammar. Nonetheless we did consider those points which would need to be handled in a thorough treatment. We present them here, as a possible basis for later work.

a. Choice between V and N in transformations

Many of the UCLA transformations have structural descriptions of the form

$$\begin{Bmatrix} V \\ N \end{Bmatrix} \quad [\ \ldots \qquad\qquad]$$

where what is meant is that there is either an N or a V which has the subanalysis given in the square brackets. In our notation this cannot be so simply stated since the obvious translation

$$(V, N) \quad (\ \ldots \qquad\qquad)$$

is not syntactically well formed. In the system, a *structure* cannot have a *choice* as head *element*. Thus, the above must be stated in the equivalent form

(V (...), N (...))

It should be noted however that the UCLA statements of the form above point to a somewhat spurious generalization, since they are generally accompanied by rather strong conditions to distinguish cases acceptable for V from those acceptable by N. The need for these conditions makes our required form seem less offensive.

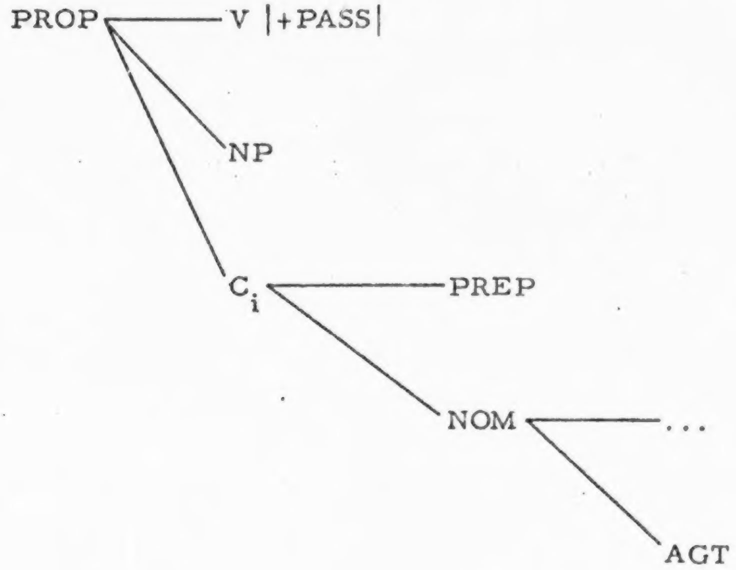
b. Distinguished role of the sentence symbol

In the system the sentence-symbol S is distinguished in several ways: i) it is the only recursive symbol in the phrase-structure, ii) the phrase-structure generation routine will not introduce an S unless it is explicitly called for by the skeleton, iii) the analysis routine will not search below an S unless the S is explicitly given in the structural description.

The parallelism in a case grammar between S and NOM suggests that they should be treated alike in all three respects. i) In stating the phrase-structure for the UCLA grammar it was necessary to repeat several times the expansion rules for NOM. This would be unnecessary if NOM as well as S were recursive. If this were true, then ii) would also need to be extended to NOM to avoid oversize generations. iii) A technical error in the UCLA grammar arose from the failure to notice that one of the implications of the lexicalist-class hypothesis is that a case node following a V may not be the case for that V, but rather a case node associated with a NOM under some other case node [see M-11]. For example, in the tree below, the structural description

$$\text{X} \quad \underset{|+\text{PASS}|}{\left\{\begin{matrix}\text{N}\\\text{V}\end{matrix}\right\}} \quad \text{NP} \quad \text{X} \quad \text{AGT} \quad \text{X}$$

selects the AGT under the first NOM, not the (intended) one immediately under the PROP.



where C_i is either DAT or LOC. This would cause trouble were it not ruled out by extra-grammatical arguments. (The documentation of the grammar indicates that every +PASS verb requires an AGT.) However, there are transformations of the grammar which do fail for this reason.

c. Cycling in the control program.

The system is designed so that the traffic rules need not be limited to cycles on S only. (See Nagara and Smith [M-7] for an example of cycling on NP). The UCLA document does not consider cycling at all, but the form of the lexicalist theory suggests that the standard LOWESTS cycle should probably be reconsidered in favor of cycling on both S and NP.

d. $\bar{\bar{X}}$, $\bar{X}$ and X

The use of PROP, NOM, etc. in the UCLA grammar is designed as a representation for Chomsky's $\bar{\bar{X}}$, $\bar{X}$ and X, where X is a variable taking the values V and N. The present notation does not automatically display the relationship between PROP and V as $\bar{V}$ and V. A feature representation could do this: V|2 BAR|, V|1 BAR|, V|0 BAR|. It would be interesting to see how this change of notation would affect the statement of the transformations.

Acknowledgement. I would like to acknowledge the assistance of Paul Myslenski, a first-year graduate student in computer and communication sciences at Michigan, who did much of the work of translating the UCLA grammar into computer-acceptable form, and of Yves Ch. Morin, who programmed the special features of the phonology component.

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Some Tables from
A Syntactical Analysis of Some First-Grade Readers

by

Elizabeth Gammon

TABLE 1

Utterance Count

Text	Pre-Primer	Primer	Reader	Total
Ginn	858	1343	1925	4126
Scott-Foresman	638	1040	1450	3128
Totals	1496	2383	3375	7254

TABLE 2

Parts of Speech in Corpus

Part of Speech	Abbreviation	Example	Examples of Types Containing more than 1 Word
adjective	A	pretty	
adverb	ADV	fast	
article	T	the	
common noun	N	house	ice cream
conjunction	C	and	
copulative verb	CV	is	
interjection	I	oh	
interrogative adjective	IADJ	which	
interrogative adverb	IADV	how	
interrogative pronoun, objective case	IP(2)	whom	
interrogative pronoun, subjective case	IP(1)	who	
intransitive verb	IV	go	
locative	L	here	
modal	M	can	
negation	-	not	
number used in counting	NBR	one	
preposition	J	into	
pronoun, objective case	P(2)	him	
pronoun, subjective case	P(1)	he	
proper noun	G	Betty	Mr. Green, Frisky Kitten
rejoinder	R	yes	all right, thank you
relative pronoun, objective case	RP(2)	whom	
relative pronoun, subjective case	RP(1)	who	
salutation	S	hello	Good day, Happy birthday
sound	Z	zoom	
subordinate conjunction	CON	that	
"to" used with infinitives	O	to	
transitive verb	TV	want	
vocative	K	Betty	Mr. Green, Frisky Kitten

TABLE 4

Statistics for Utterance Types under Original Classification

Text	Total Number of Types	% of Types with Frequency > 5	% of Types with Frequency > 1
Ginn Pre-Primer	250	10.4	45.2
Scott-Foresman Pre-Primer	277	8.3	28.9
Pre-Primers Combined	454	10.1	39.9
Ginn Primer	664	5.0	28.8
Scott-Foresman Primer	666	3.3	19.1
Primers Combined	1185	4.6	26.3
Ginn Reader	1099	3.3	25.8
Scott-Foresman Reader	1096	1.6	12.8
Readers Combined	2015	2.9	21.3

TABLE 6

Comparison of Collapses

Section of Corpus	Original No. of Types	Original % of Types with Freq. > 5	Original % of Types with Freq. > 1	Noun Phrase and Verb Phrase Collapsing No. of Types	Noun Phrase and Verb Phrase Collapsing % of Types with Freq. > 5	Noun Phrase and Verb Phrase Collapsing % of Types with Freq. > 1	Final No. of Types	Final % of Types with Freq. > 5	Final % of Types with Freq. > 1
Pre-Primers Combined	454	10.1	39.9	218	21.1	52.8	153	24.2	57.5
Primers Combined	1185	4.6	26.3	528	15.5	42.2	364	17.3	46.2
Readers Combined	2015	2.9	21.3	996	9.8	32.0	689	11.6	35.3

TABLE 10

Rewrite Rules of the Noun-Phrase Grammar

$NP \rightarrow P$

$NP \rightarrow G$

$NP \rightarrow (T) + \left(\left\{\begin{matrix}A\\A+A\end{matrix}\right\}\right) + N$

$NP \rightarrow A + A + A + N$

TABLE 11

Rewrite Rules and Parameters of the Noun-Phrase Grammar

Rewrite Rules	Parameters		
	Rule-Choice Probabilities	Within-Rule-Choice Probabilities	
$NP \rightarrow P$	A_1		
$NP \rightarrow G$	A_2		
$NP \rightarrow (T) + \left(\left\{\begin{matrix}A\\A+A\end{matrix}\right\}\right) + N$	A_3	$B1_1$ $B1_2$	$B2_1$ $B2_2$ $B2_3$
$NP \rightarrow A + A + A + N$	A_4		

TABLE 13

Percent of each Section of the Corpus Accounted for by the Noun-Phrase Grammar

Ginn Pre-Primer	S-F Pre-Primer	Pre-Primers Combined	Ginn Primer	S-F Primer	Primers Combined	Ginn Reader	S-F Reader	Readers Combined	All Combined
99.0	98.1	98.6	98.6	97.8	98.2	98.7	97.3	98.0	98.2

TABLE 14

Maximum-likelihood Estimates for each Section of the Corpus for the Noun-Phrase Grammar

Parameter	Ginn Pre-Primer	S-F Pre-Primer	Pre-Primers Combined	Ginn Primer	S-F Primer	Primers Combined	Ginn Reader	S-F Reader	Readers Combined	All Combined
A_1	.2979	.6309	.4529	.4369	.5290	.4803	.3710	.3761	.3733	.4171
A_2	.3290	.1964	.2673	.1719	.1484	.1608	.1535	.1218	.1389	.1635
A_3	.3718	.1726	.2791	.3810	.3205	.3525	.4677	.4960	.4808	.4135
A_4	.0013	.0000	.0007	.0102	.0020	.0064	.0078	.0060	.0070	.0059
Bl_1	.6272	.4741	.5831	.5820	.5453	.5663	.6142	.4631	.5421	.5522
Bl_2	.3728	.5259	.4169	.4180	.4547	.4337	.3858	.5369	.4579	.4477
$B2_1$	.2265	.3276	.2556	.3502	.3958	.3697	.3338	.3939	.3625	.3543
$B2_2$	.0871	.0776	.0844	.1561	.1495	.1533	.1312	.0973	.1150	.1221
$B2_3$	.6864	.5948	.6600	.4937	.4547	.4770	.5350	.5087	.5225	.5237

TABLE 15

Comparison of Total Chi-Squares for Noun-Phrase Grammar

Text	No. of Phrases Accounted For	Total Chi-Square	Degrees of Freedom
Ginn Pre-Primer	772	.5	1
Scott-Foresman Pre-Primer	672	2.3	0
Pre-Primers Combined	1444	1.3	1
Ginn Primer	1664	52.2	2
Scott-Foresman Primer	1482	42.6	1
Primers Combined	3146	95.3	2
Ginn Reader	3081	81.5	2
Scott-Foresman Reader	2651	177.5	2
Readers Combined	5732	247.6	2
All Combined	10322	316.8	2

TABLE 16

Observed and Expected Frequencies, Chi-Square Contributions, and Total Chi-Squares for each Section of the Corpus for Noun-Phrase Grammar

GINN PRE-PRIMER

```
OBSERV.  EXPECT.  CHI**2  SOURCE

  230     230.0      .0   P
  254     254.0      .0   G
   76      73.4      .1   N
   23      24.2      .1   A+N
    8       9.3      .2   A+A+N
  121     123.6      .1   T+N
   42      40.8      .0   T+A+N
   17      15.7      .1   T+A+A+N
    1       1.0           A+A+A+N


    1       1.0           RESIDUAL

  772     772.0      .5   TOTAL

                    1     DEGREES OF FREEDOM
```

SCOTT-FORESMAN PRE-PRIMER

```
OBSERV.  EXPECT.  CHI**2  SOURCE

  424     424.0      .0   P
  132     132.0      .0   G
   33      36.3      .3   N
   24      20.0      .8   A+N
    4       4.7           A+A+N
   36      32.7      .3   T+N
   14      18.0      .9   T+A+N
    5       4.3           T+A+A+N

    9       9.0      .0   EXPECTED FREQ. LESS THAN 5.0

    0        .0           A+A+A+N


    0        .0           RESIDUAL

  672     672.0     2.3   TOTAL

                    0     DEGREES OF FREEDOM
```

TABLE 16 (continued)

PRE-PRIMERS COMBINED

```
OBSERV.   EXPECT.   CHI**2  SOURCE

  654      654.0       .0   P
  386      386.0       .0   G
  109      110.9       .0   N
   47       42.9       .4   A+N
   12       14.2       .3   A+A+N
  157      155.1       .0   T+N
   56       60.1       .3   T+A+N
   22       19.8       .2   T+A+A+N
    1        1.0            A+A+A+N


    1        1.0            RESIDUAL

 1444     1444.0      1.3   TOTAL

                      1     DEGREES OF FREEDOM
```

GINN PRIMER

```
OBSERV.   EXPECT.   CHI**2  SOURCE

  727      727.0       .0   P
  286      286.0       .0   G
   86      130.8     15.4   N
  123       92.8      9.8   A+N
   56       41.4      5.2   A+A+N
  227      182.2     11.0   T+N
   99      129.2      7.1   T+A+N
   43       57.6      3.7   T+A+A+N
   17       17.0       .0   A+A+A+N


    0         .0            RESIDUAL

 1664     1664.0     52.2   TOTAL

                      2     DEGREES OF FREEDOM
```

TABLE 16 (continued)

SCOTT-FORESMAN PRIMER

```
OBSERV.  EXPECT.  CHI**2  SOURCE

  784     784.0      .0   P
  220     220.0      .0   G
   63      98.2    12.6   N
  110      85.5     7.0   A+N
   43      32.3     3.6   A+A+N
  153     117.8    10.5   T+N
   78     102.5     5.9   T+A+N
   28      38.7     3.0   T+A+A+N
    3       3.0           A+A+A+N


    3       3.0           RESIDUAL

 1482    1482.0    42.6   TOTAL

              1           DEGREES OF FREEDOM
```

PRIMERS COMBINED

```
OBSERV.  EXPECT.  CHI**2  SOURCE

 1511    1511.0      .0   P
  506     506.0      .0   G
  149     229.4    28.2   N
  233     177.8    17.1   A+N
   99      73.7     8.7   A+A+N
  380     299.6    21.6   T+N
  177     232.2    13.1   T+A+N
   71      96.3     6.6   T+A+A+N
   20      20.0      .0   A+A+A+N


    0        .0           RESIDUAL

 3146    3146.0    95.3   TOTAL

              2           DEGREES OF FREEDOM
```

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TABLE 16 (continued)

GINN READER

```
OBSERV.  EXPECT.  CHI**2  SOURCE

 1143    1143.0      .0  P
  473     473.0      .0  G
  215     297.5    22.9  N
  238     185.6    14.8  A+N
  103      72.9    12.4  A+A+N
  556     473.5    14.4  T+N
  243     295.4     9.3  T+A+N
   86     116.1     7.8  T+A+A+N
   24      24.0      .0  A+A+A+N


    0        .0          RESIDUAL

 3081    3081.0    81.5  TOTAL

                   2     DEGREES OF FREEDOM
```

SCOTT-FORESMAN READER

```
OBSERV.  EXPECT.  CHI**2  SOURCE

  997     997.0      .0  P
  323     323.0      .0  G
  239     359.2    40.2  N
  370     278.1    30.4  A+N
   97      68.7    11.6  A+A+N
  430     309.8    46.6  T+N
  148     239.9    35.2  T+A+N
   31      59.3    13.5  T+A+A+N
   16      16.0      .0  A+A+A+N


    0       -.0          RESIDUAL

 2651    2651.0   177.5  TOTAL

                   2     DEGREES OF FREEDOM
```

TABLE 16 (continued)

READERS COMBINED

```
OBSERV.  EXPECT.  CHI**2  SOURCE

  2140    2140.0      .0  P
   796     796.0      .0  G
   454     659.4    64.0  N
   608     457.5    49.5  A+N
   200     145.2    20.7  A+A+N
   986     780.6    54.0  T+N
   391     541.5    41.9  T+A+N
   117     171.8    17.5  T+A+A+N
    40      40.0      .0  A+A+A+N


     0        .0          RESIDUAL

  5732    5732.0   247.6  TOTAL

                   2      DEGREES OF FREEDOM
```

ALL COMBINED

```
OBSERV.  EXPECT.  CHI**2  SOURCE

  4305    4305.0      .0  P
  1688    1688.0      .0  G
   712    1000.7    83.3  N
   888     677.0    65.8  A+N
   311     233.3    25.9  A+A+N
  1523    1234.3    67.5  T+N
   624     835.0    53.3  T+A+N
   210     287.7    21.0  T+A+A+N
    61      61.0      .0  A+A+A+N


     0       -.1          RESIDUAL

 10322   10322     316.8  TOTAL

                   2      DEGREES OF FREEDOM
```

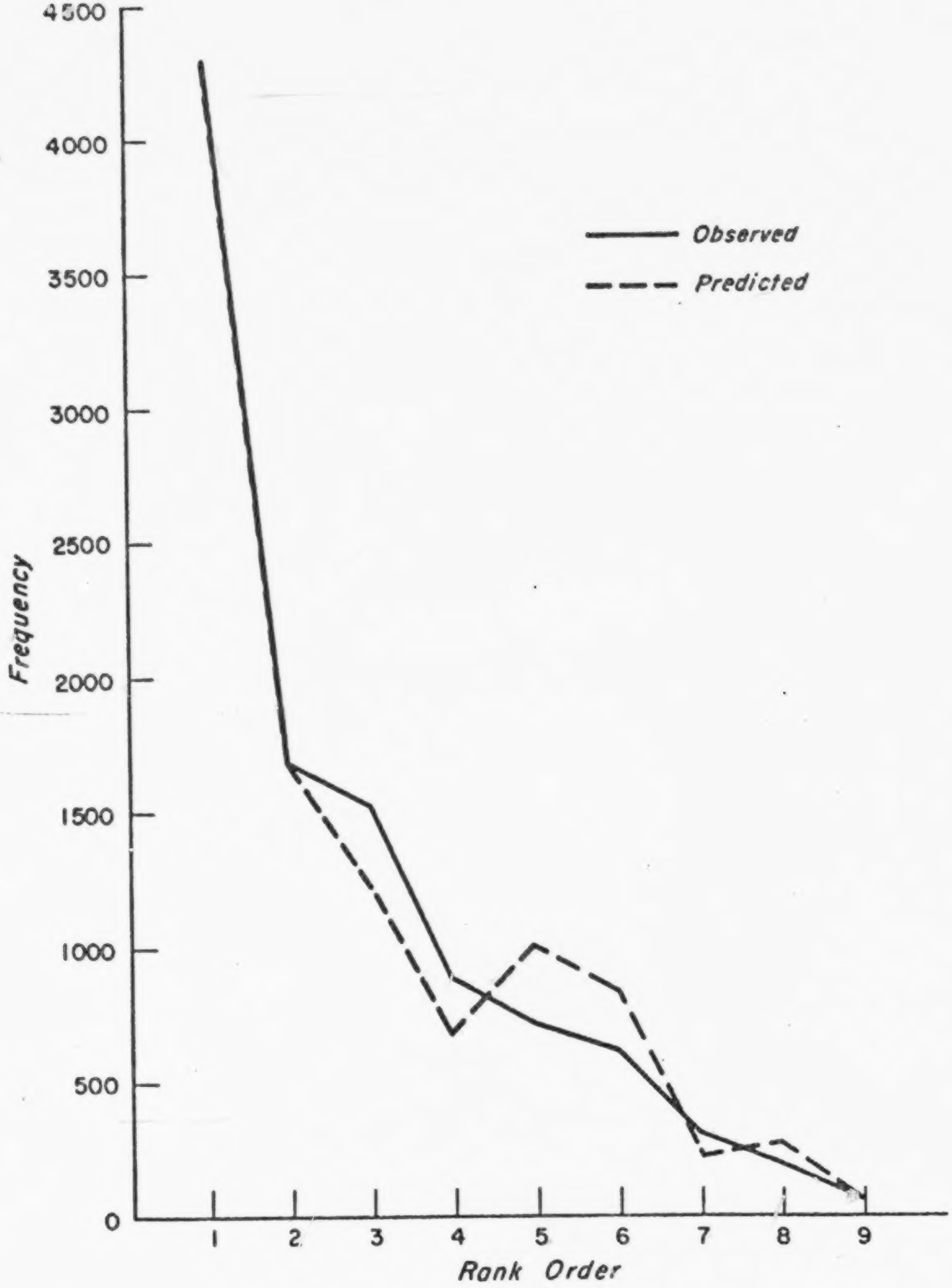

Fig. 1. Comparison of observed and predicted frequencies for noun phrases (entire corpus).

TABLE 37

The Grammar for Statements with Verbs

Rewrite Rules	Parameters: Rule-Choice Probabilities	Parameters: Within-Rule-Choice Probabilities
I. Statements with single subject, single predicate, and no embedding:		
1. $S \rightarrow \left(\begin{Bmatrix} C \\ VM \end{Bmatrix}\right) + NP_{i,j,1} + VP_{i,j} + NP_{k,\ell,2} + \left(\left(\begin{matrix} K \\ VM \end{matrix}\right)\right)$	A_1	$B1_1$ $B2_1$ $B1_2$ $B2_2$ $B1_3$ $B2_3$
2. $S \rightarrow \left(\begin{Bmatrix} R \\ C \\ VM \end{Bmatrix}\right) + NP_{i,j,1} + VP_{i,j} + (VM) + (K)$	A_2	$B3_1$ $B3_2$ $B4_1$ $B5_1$ $B3_3$ $B4_2$ $B5_2$ $B3_4$
3. $S \rightarrow (VM) + VP_{i,2} + NP_{k,\ell,2} + \left(\left(\begin{matrix} K \\ VM \end{matrix}\right)\right)$	A_3	$B2_1$ $B6_1$ $B2_2$ $B6_2$ $B2_3$
4. $S \rightarrow (VM) + VP_{i,2} + (VM) + (K)$	A_4	$B6_1$ $B4_1$ $B5_1$ $B6_2$ $B4_2$ $B5_2$
5. $S \rightarrow NP_{i,j,1} + VP_{i,j} + VM + NP_{k,\ell,2}$	A_5	
6. $S \rightarrow NP_{i,j,1} + VM + VP_{i,j} + VM$	A_6	
7. $S \rightarrow C + VM + NP_{i,j,1} + VP_{i,j}$	A_7	
8. $S \rightarrow NP_{i,j,1} + VP_{i,j} + (VM) + A + \left(\left(\begin{matrix} K \\ VM \end{matrix}\right)\right)$	A_{12}	$B2_1$ $B9_1$ $B2_2$ $B9_2$ $B2_3$
9. $S \rightarrow VP_{i,2} + VM + A + K$	A_{13}	

TABLE 37 (continued)

II. Statements with compound subjects or compound predicates:

10.	$S \rightarrow VP_{i,2}+C+VP_{i,2}+(NP_{k,\ell,2})+\left(\begin{Bmatrix}K\\VM\end{Bmatrix}\right)$	A_8	$B7_1$ $B7_2$ $B2_1$ $B2_2$ $B2_3$
11.	$S \rightarrow NP_{i,j,1}+VP_{i,j}+C+VP_{i,j}+(NP_{k,\ell,2})+(VM)$	A_9	$B7_1$ $B7_2$ $B4_1$ $B4_2$
12.	$S \rightarrow (VM)+NP_{i,j,1}+C+NP_{k,\ell,1}+VP_{2,\ell}+(NP_{m,n,2})+(VM)$	A_{10}	$B6_1$ $B6_2$ $B7_1$ $B7_2$ $B4_1$ $B4_2$
13.	$S \rightarrow (VM)+(NP_{i,j,1})+VP_{i,j}+NP_{k,\ell,2}+C+NP_{m,n,2}+(VM)$ where j = 2 if $NP_{i,j,1}$ is deleted	A_{11}	$B6_1$ $B6_2$ $B8_1$ $B8_2$ $B4_1$ $B4_2$

III. Statements with embedding:

14.	$S \rightarrow (VM)+(NP_{i,j,1})+VP_{i,j}+NP_{k,\ell,2}+VP_3+(VM)$ where j = 2 if $NP_{i,j,1}$ is deleted	A_{15}	$B6_1$ $B6_2$ $B8_1$ $B8_2$ $B4_1$ $B4_2$
15.	$S \rightarrow (NP_{i,j,1})+VP_{i,j}+NP_{k,\ell,2}+VP_3+NP_{m,n,2}+(VM)$ where j = 2 if $NP_{i,j,1}$ is deleted	A_{16}	$B8_1$ $B8_2$ $B4_1$ $B4_2$
16.	$S \rightarrow (NP_{i,j,1})+VP_{i,j}+\begin{Bmatrix}RP_{k,\ell,2}\\NP_{k,\ell,2}\end{Bmatrix}+NP_{m,n,1}+VP_{m,n}+\left(\begin{Bmatrix}O+VP_3\\VM\end{Bmatrix}\right)$ where j = 2 if $NP_{i,j,1}$ is deleted	A_{17}	$B8_1$ $B8_2$ $B10_1$ $B10_2$ $B11_1$ $B11_2$ $B11_3$
17.	$S \rightarrow (VM)+NP_{i,j,1}+VP_{i,j}+O+VP_3+(NP_{k,\ell,2})+(VM)$	A_{18}	$B6_1$ $B6_2$ $B7_1$ $B7_2$ $B4_1$ $B4_2$
18.	$S \rightarrow NP_{i,j,1}+VP_{i,j}+NP_{i,\ell,2}+O+VP_3+\left(\begin{Bmatrix}NP_{m,n,2}\\NP_{m,n,2}+VP_3\end{Bmatrix}\right)+(VM)$	A_{19}	$B12_1$ $B12_2$ $B12_3$ $B4_1$ $B4_2$
19.	$S \rightarrow NP_{i,j,1}+C+NP_{k,\ell,1}+VP_{2,\ell}+O+VP_3+VM$	A_{20}	
20.	$S \rightarrow NP_{i,j,1}+VP_{i,j}+VM+O+VP_3$	A_{21}	
21.	$S \rightarrow NP_{i,j,1}+VP_{i,j}+O+VP_3+NP_{k,\ell,2}+VP_3$	A_{22}	
22.	$S \rightarrow NP_{i,j,1}+VP_{i,j}+A+O+VP_3+(VM)$	A_{14}	$B4_1$ $B4_2$

TABLE 37 (continued)

23. $S \rightarrow NP_{i,j,1}+VP_{i,j}+CON+O+VP_3$ $\qquad A_{23}$

24. $S \rightarrow NP_{i,j,1}+VP_{i,j}+(NP_{k,\ell,2})+(VM)+CON+NP_{m,n,1}+\left(\left\{\begin{matrix} VP_{m,n} \\ VP_{m,n}+VM \end{matrix}\right\}\right)$ $\qquad A_{24}$

$$\begin{array}{ccc} & & B13_1 \\ B7_1 & B4_1 & B13_2 \\ B7_2 & B4_2 & B13_3 \end{array}$$

in $NP_{i,j,k}$ = $i = 1,2$ = number
$j = 1,2,3$ = person
$k = 1,2$ = case

in $VP_{i,j}$ = $i = 1,2$ = number
$j = 1,2,3$ = person

$VP_3 \Rightarrow$ infinitive form (verbs lacking infinitive form may not be used)

Obligatory transformations:

1. If "VM" is an adverbial phrase of location or direction (for example: here, up, away, then up, off to the store), or if "VM" is one of these descriptions: "hippity-hop", "faster and faster", "swish", "swish, swish", "hop, hop", "splash, splash", "left foot first", "right foot first", and if "$VP_{i,j}$" is a form of "to be" or one of these verbs of locomotion: "walk", "jump", "go", "run", "come", "roll", "buzz", and if $NP_{i,j,1} \neq P$, then

$$(C)+VM+NP_{i,j,1}+VP_{i,j}+\ldots \rightarrow (C)+VM+VP_{i,j}+NP_{i,j,1}+\ldots$$

2. If "VM" is "so" and "$VP_{i,j}$" is a form of "to be" or "to do", or is: "can", "could", "may", "will", "shall", or "must", then

$$VM+NP_{i,j,1}+VP_{i,j} \rightarrow VM+VP_{i,j}+NP_{i,j,1}$$

3. If "$VP_{i,j}$" is a form of "to be", then

$$\ldots+VP_{i,j}+NP_{k,\ell,2}+\ldots \rightarrow \ldots+VP_{i,j}+NP_{k,\ell,1}+\ldots$$

4. If "$NP_{i,j,1}$" is "what + NP", then

$$\ldots+NP_{i,j,1}+VP_{i,j,1}+NP_{k,\ell,2}+\ldots \rightarrow \ldots+NP_{k,\ell,2}+NP_{i,j,1}+VP_{i,j}+\ldots$$

5. If "$VP_{i,j}$" is a form of: "to wish", "to think", "to say", "to guess", or "to know", then

$$\ldots+NP_{i,j,1}+VP_{i,j}+NP_{k,\ell,2}+VP_3+\ldots \rightarrow \ldots+NP_{i,j,1}+VP_{i,j}+NP_{k,\ell,1}+VP_{k,\ell}+\ldots$$

TABLE 39

Percent of each Section of the Corpus Accounted for by the Grammar for Statements with Verbs

Ginn Pre-Primer	S-F Pre-Primer	Pre-Primers Combined	Ginn Primer	S-F Primer	Primers Combined	Ginn Reader	S-F Reader	Readers Combined	All Combined
93.9	87.4	91.2	90.6	83.5	87.5	88.5	72.6	81.8	85.5

TABLE 41

Comparison of Total Chi-Squares for the Grammar for Statements with Verbs

Text	No. of Statements Accounted For	Total Chi-Square	Degrees of Freedom
Pre-Primers Combined	1072	364.7	2
Ginn Primer	892	249.6	8
Scott-Foresman Primer	636	254.2	7
Primers Combined	1528	478.3	26
Ginn Reader	1387	406.3	25
Scott-Foresman Reader	835	206.0	15
Readers Combined	2222	729.2	44
All Combined	4822	1644.0	61

TABLE 42 (continued)

ALL COMBINED

OBSERV.	EXPECT.	CHI**2	SOURCE
653	668.1	.3	NP(1)+VP+NP(2)
31	54.6	10.2	NP(1)+VP+NP(2)+K
363	324.3	4.6	NP(1)+VP+NP(2)+VM
47	45.3	.1	C+NP(1)+VP+NP(2)
1	3.7		C+NP(1)+VP+NP(2)+K
23	22.0	.0	C+NP(1)+VP+NP(2)+VM
88	81.0	.6	VM+NP(1)+VP+NP(2)
1	6.6	4.8	VM+NP(1)+VP+NP(2)+K
38	39.3	.0	VM+NP(1)+VP+NP(2)+VM
108	223.8	59.9	NP(1)+VP
601	354.0	172.4	NP(1)+VP+VM
3	54.7	48.9	NP(1)+VP+K
7	86.5	73.1	NP(1)+VP+VM+K
20	6.5	27.7	R+NP(1)+VP
1	10.3	8.4	R+NP(1)+VP+VM
0	1.6		R+NP(1)+VP+K
1	5.3	3.5	EXPECTED FREQ. LESS THAN 5.0
0	2.5		R+NP(1)+VP+VM+K
26	27.1	.0	C+NP(1)+VP
59	42.8	6.1	C+NP(1)+VP+VM
0	6.6	6.6	C+NP(1)+VP+K
2	10.5	6.9	C+NP(1)+VP+VM+K
268	164.0	65.9	VM+NP(1)+VP
240	259.5	1.5	VM+NP(1)+VP+VM
17	40.1	13.3	VM+NP(1)+VP+K
2	63.4	59.5	VM+NP(1)+VP+VM+K
124	126.9	.1	VP+NP(2)
34	10.4	53.9	VP+NP(2)+K
27	61.6	19.4	VP+NP(2)+VM
18	12.9	2.0	VM+VP+NP(2)
3	1.1		VM+VP+NP(2)+K
13	6.3	7.3	VM+VP+NP(2)+VM
95	214.5	66.6	VP
253	339.2	21.9	VP+VM
221	82.9	230.0	VP+VM+K
3	8.4	3.5	VM+VP+VM+K
156	52.4	204.7	VP+K
4	5.3	.3	VM+VP+K
4	21.8	14.5	VM+VP
23	34.4	3.8	VM+VP+VM
13	13.0	.0	NP(1)+VP+VM+NP(2)
7	7.0	.0	NP(1)+VM+VP+VM
9	9.0	.0	C+VM+NP(1)+VP
28	52.5	11.4	VP+C+VP
72	38.2	30.0	VP+C+VP+NP(2)
25	25.5	.0	VP+C+VP+VM

TABLE 42 (continued)

8	4.3		VP+C+VP+K
11	7.9	1.3	EXPECTED FREQ. LESS THAN 5.0
3	18.5	13.0	VP+C+VP+NP(2)+VM
6	3.1		VP+C+VP+NP(2)+K
23	11.2	12.4	NP(1)+VP+C+VP
13	8.2	2.9	NP(1)+VP+C+VP+NP(2)
15	17.7	1.3	VP(1)+VP+C+VP+VM
1	12.9	11.0	NP(1)+VP+C+VP+NP(2)+VM
10	23.6	7.8	NP(1)+C+NP(1)+VP
19	17.2	.2	NP(1)+C+NP(1)+VP+NP(2)
12	27.2	8.5	NP(1)+C+NP(1)+VP+NP(2)+VM
39	37.3	.1	NP(1)+C+NP(1)+VP+VM
21	2.4		VM+NP(1)+C+NP(1)+VP
27	5.5	83.7	EXPECTED FREQ. LESS THAN 5.0
4	1.7		VM+NP(1)+C+NP(1)+VP+NP(2)
2	2.8		VM+NP(1)+C+NP(1)+VP+NP(2)+VM
9	3.8		VM+NP(1)+C+NP(1)+VP+VM
15	8.3	5.4	EXPECTED FREQ. LESS THAN 5.0
15	10.0	2.5	VP+NP(2)+C+NP(2)
0	15.8	15.8	VP+NP(2)+C+NP(2)+VM
33	11.5	40.4	NP(1)+VP+NP(2)+C+NP(2)
6	18.2	8.1	NP(1)+VP+NP(2)+C+NP(2)+VM
0	1.0		VM+VP+NP(2)+C+NP(2)
1	1.6		VM+VP+NP(2)+C+NP(2)+VM
6	1.2		VM+NP(1)+VP+NP(2)+C+NP(2)
0	1.8		VM+NP(1)+VP+NP(2)+C+NP(2)+VM
7	5.6	.3	EXPECTED FREQ. LESS THAN 5.0
62	63.2	.0	NP(1)+VP+A
10	14.0	1.2	NP(1)+VP+VM+A
6	5.2	.1	NP(1)+VP+A+K
0	1.1		NP(1)+VP+VM+A+K
31	30.7	.0	NP(1)+VP+A+VM
12	6.8	3.9	NP(1)+VP+VM+A+VM
5	5.0	.0	VP+VM+A+K
7	7.7	.1	NP(1)+VP+A+O+VP
13	12.3	.0	NP(1)+VP+A+O+VP+VM
42	20.4	22.8	VP+NP(2)+VP
32	32.3	.0	VP+NP(2)+VP+VM
15	23.5	3.1	NP(1)+VP+NP(2)+VP
29	37.2	1.8	NP(1)+VP+NP(2)+VP+VM
0	2.1		VM+VP+NP(2)+VP
0	3.3		VM+VP+NP(2)+VP+VM
0	6.5	6.5	EXPECTED FREQ. LESS THAN 5.0

TABLE 42 (continued)

0	2.4		VM+ NP (1)+VP+NP (2)+VP
7	3.8		VM+ NP (1)+VP+NP (2)+VP+VM
7	6.2	.1	EXPECTED FREQ. LESS THAN 5.0
18	11.2	4.2	VP+NP (2)+VP+NP (2)
15	17.7	.4	VP+NP (2)+VP+NP (2)+VM
15	12.9	.4	NP (1)+VP+NP (2)+VP+NP (2)
14	20.3	2.0	NP (1)+VP+NP (2)+VP+NP (2)+VM
21	24.6	.5	VP+NP (2)+NP (1)+VP
2	5.5	2.2	VP+NP (2)+NP (1)+VP+VM
0	2.0		VP+NP (2)+NP (1)+VP+0+VP
39	28.3	4.1	NP (1)+VP+NP (2)+NP (1)+VP
5	6.3	.3	NP (1)+VP+NP (2)+NP (1)+VP+VM
2	2.4		NP (1)+VP+NP (2)+NP (1)+VP+0+VP
5	8.9	1.7	VP+RP (2)+NP (1)+VP
8	2.0		VP+RP (2)+NP (1)+VP+VM
10	6.4	2.1	EXPECTED FREQ. LESS THAN 5.0
0	.7		VP+RP (2)+NP (1)+VP+0+VP
7	10.2	1.0	NP (1)+VP+RP (2)+NP (1)+VP
1	2.3		NP (1)+VP+RP (2)+NP (1)+VP+VM
4	.9		NP (1)+VP+RP (2)+NP (1)+VP+0+VP
33	59.6	11.9	NP (1)+VP+0+VP
92	43.4	54.5	NP (1)+VP+0+VP+NP (2)
31	68.6	20.6	NP (1)+VP+0+VP+NP (2)+VM
110	94.3	2.6	NP (1)+VP+0+VP+VM
9	6.1	1.4	VM+ NP (1)+VP+0+VP
7	4.4		VM+ NP (1)+VP+0+VP+NP (2)
12	8.3	1.7	EXPECTED FREQ. LESS THAN 5.0
0	7.0	7.0	VM+ NP (1)+VP+0+VP+NP (2)+VM
11	9.6	.2	VM+ NP (1)+VP+0+VP+VM
25	17.0	3.7	NP (1)+VP+NP (2)+0+VP
21	10.1	11.9	NP (1)+VP+NP (2)+0+VP+NP (2)
0	.0		NP (1)+VP+NP (2)+0+VP+NP (2)+VP
19	27.0	2.3	NP (1)+VP+NP (2)+0+VP+VM
5	15.9	7.5	NP (1)+VP+NP (2)+0+VP+NP (2)+VM
0	.0		NP (1)+VP+NP (2)+0+VP+NP (2)+VP+VM
5	5.0	.0	NP (1)+C+NP (1)+VP+0+VP+VM
5	5.0	.0	NP (1)+VP+VM+0+VP
9	9.0	.0	NP (1)+VP+0+VP+NP (2)+VP
5	5.0	.0	NP (1)+VP+CON+0+VP
0	2.9		NP (1)+VP+CON+NP (1)
5	2.9		NP (1)+VP+CON+NP (1)+VP
5	5.8	.1	EXPECTED FREQ. LESS THAN 5.0
6	1.6		NP (1)+VP+CON+NP (1)+VP+VM
0	2.1		NP (1)+VP+NP (2)+CON+NP (1)
0	2.1		NP (1)+VP+NP (2)+CON+NP (1)+VP

TABLE 42 (continued)

```
   6      5.8       .0  EXPECTED FREQ. LESS THAN 5.0

   0      1.1           NP(1)+VP+NP(2)+CON+NP(1)+VP+VM
   8      4.6           NP(1)+VP+VM+CON+NP(1)

   8      5.8       .9  EXPECTED FREQ. LESS THAN 5.0

   8      4.6           NP(1)+VP+VM+CON+NP(1)+VP
   1      2.5           NP(1)+VP+VM+CON+NP(1)+VP+VM

   9      7.1       .5  EXPECTED FREQ. LESS THAN 5.0

   5      3.4           NP(1)+VP+NP(2)+VM+CON+NP(1)
   0      3.4           NP(1)+VP+NP(2)+VM+CON+NP(1)+VP

   5      6.7       .4  EXPECTED FREQ. LESS THAN 5.0

   0      1.8           NP(1)+VP+NP(2)+VM+CON+NP(1)+VP+VM


   0      2.0           RESIDUAL

4822   4822.0   1644.0  TOTAL

                  61    DEGREES OF FREEDOM
```

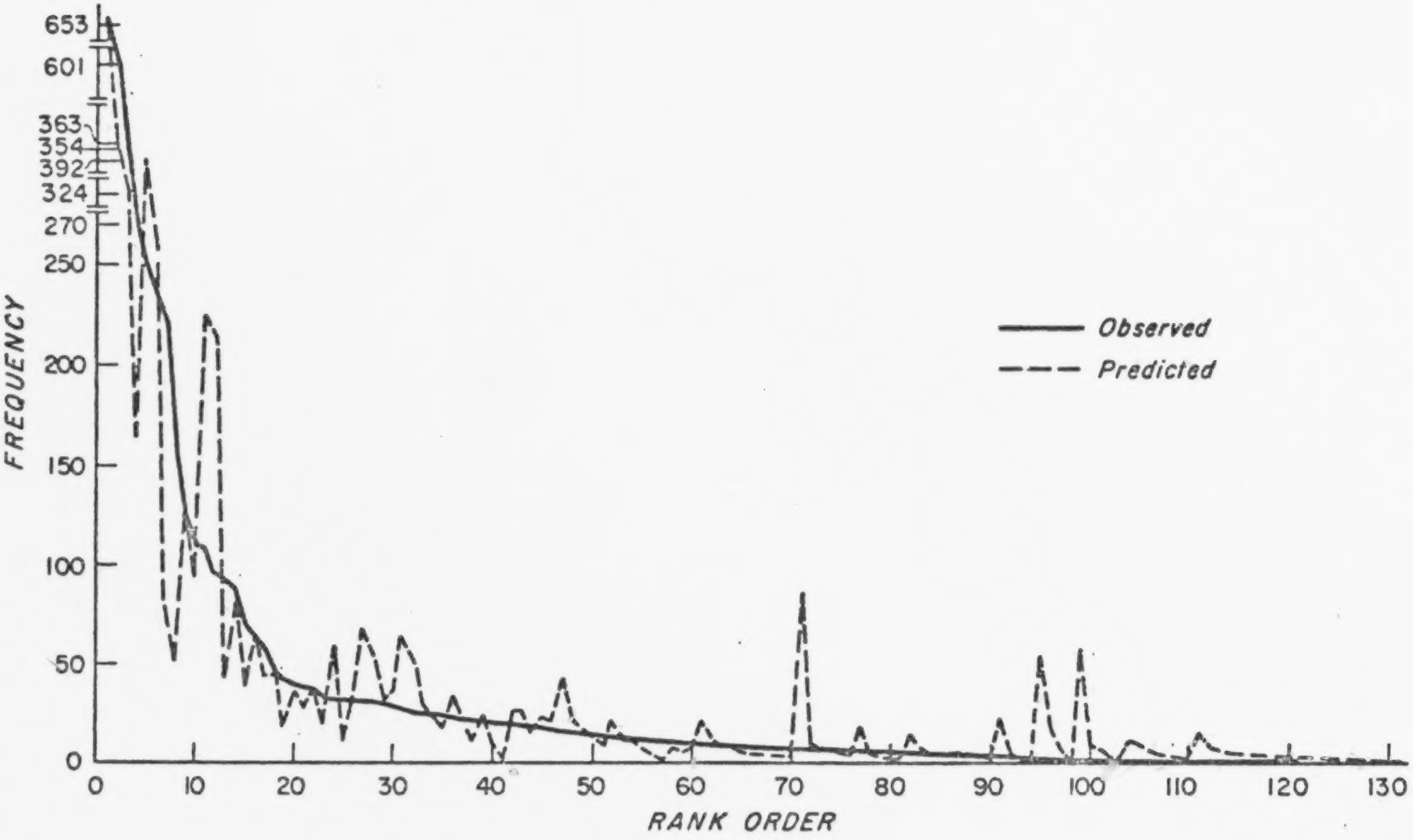

Fig. 6. Comparison of observed and predicted values for statement with verbs (entire corpus).

TABLE 45

Comparison of Total Chi-Squares for all Grammars

Text	Noun-Phrase Grammar		Verb-Phrase Grammar		Verbal-Modifier Grammar		Grammar for Statements without Verbs		Interrogative Grammar		Grammar for Statements with Verbs	
	Chi-Sq.	DF	Chi-Sq.	DF	Chi-Sq.	DF	Chi-Sq.	DF	Chi-Sq.	DF	Chi-Sq.	DF
Ginn Pre-Primer	.5	1	4.9	2	-	-	-	-	-	-	-	-
Scott-Foresman Pre-Primer	2.3	0	41.4	1	-	-	-	-	-	-	-	-
Pre-Primers Combined	1.3	1	33.5	2	-	-	-	-	-	-	364.7	2
Ginn Primer	52.2	2	34.9	3	-	-	-	-	-	-	249.6	8
Scott-Foresman Primer	42.6	1	36.9	3	-	-	-	-	-	-	254.2	7
Primers Combined	95.3	2	69.1	4	-	-	-	-	-	-	478.3	26
Ginn Reader	81.5	2	72.9	3	-	-	-	-	-	-	406.3	25
Scott-Foresman Reader	177.5	2	12.9	3	-	-	-	-	-	-	206.0	15
Readers Combined	247.6	2	57.3	4	-	-	-	-	-	-	729.2	44
All Combined	316.8	2	159.1	4	9.6	5	13.0	3	52.3	2	1644.0	6.1

TABLE 46

Average "Chi-Squares" for all Grammars

Text	Noun-Phrase Grammar	Verb-Phrase Grammar	Verbal Modifier Grammar	Grammar for Statements without Verbs	Interrogative Grammar	Grammar for Statements with Verbs
Ginn Pre-Primer	.5	2.5	-	-	-	-
S-F Pre-Primer	-	41.4	-	-	-	-
Pre-Primers Combined	1.3	16.8	-	-	-	182.4
Ginn Primer	26.1	11.6	-	-	-	31.2
Scott-Foresman Primer	42.6	12.3	-	-	-	36.3
Primers Combined	47.7	17.3	-	-	-	18.4
Ginn Reader	40.8	24.3	-	-	-	16.3
Scott-Foresman Reader	88.8	4.3	-	-	-	13.7
Readers Combined	123.8	14.3	-	-	-	16.6
All Combined	158.4	39.8	1.9	4.3	26.2	27.0

TABLE 47

The Categorial Grammar for Noun Phrases

Rewrite rule: $\alpha \rightarrow \alpha/\beta, \beta$

Premises from which derivations are possible: n

Premises from which no derivations are possible: p, g

Primitive categories: n

Categories:

n	(noun)
g	(proper noun)
p	(pronoun)
t	(article)
n/n	(adjective)

Obligatory transformations:

a) If "n" is "something", $n/n, n \rightarrow n, n/n$
b) If "n/n" is "what" or "all", $t, n/n, n \rightarrow n/n, t, n$
c) If "n/n_1" is "what" or "all", $t, n/n, n/n_2, n \rightarrow n/n_1, t, n/n_2, n$

Optional transformation: Any statement derivable from "n" may begin with an article, "t".

Parameters: A_1-A_3, premise choice parameters
S_1-S_2, stopping parameter
T_1-T_2, optional transformation parameter

TABLE 48

Derivations from the Categorial Grammar for Noun Phrases

Type	Derivation	Theoretical Probability
P	g	A_2
G	g	A_3
N	n	$A_1\binom{N}{0}S_1^{0}S_2^{N}T_2$
A+N	$n \rightarrow n/n, n$	$A_1\binom{N}{1}S_1^{1}S_2^{N-1}T_2$
A+A+N	$n \rightarrow n/n, n \rightarrow n/n, n/n, n$	$A_1\binom{N}{2}S_1^{2}S_2^{N-2}T_2$
T+N	n + transformation	$A_1\binom{N}{0}S_1^{0}S_2^{N}T_1$
T+A+N	$n \rightarrow n/n, n$ + transformation	$A_1\binom{N}{1}S_1^{1}S_2^{N-1}T_1$
T+A+A+N	$n \rightarrow n/n, n \rightarrow n/n, n/n, n$ + transformation	$A_1\binom{N}{2}S_1^{2}S_2^{N-2}T_1$
A+A+A+N	$n \rightarrow n/n, n \rightarrow n/n, n/n, n \rightarrow n/n, n/n, n/n, n$	$A_1\binom{N}{3}S_1^{3}S_2^{N-3}T_2$

TABLE 49

Maximum Likelihood Estimates for each Section of the Corpus for the Categorial Grammar for Noun Phrases

Para-meter	Ginn Pre-Primer	S-F Pre-Primer	Pre-Primers Combined	Ginn Primer	S-F Primer	Primers Combined	Ginn Reader	S-F Reader	Readers Combined	All Combined	All Combined N=5	All Combined N=7	All Combined N=8
A_1	.3731	.1726	.2798	.3912	.3225	.3589	.4755	.5021	.4878	.4194	.4194	.4194	.4194
A_2	.2979	.6309	.4529	.4369	.5290	.4803	.3710	.3761	.3733	.4171	.4171	.4171	.4171
A_3	.3290	.1964	.2673	.1719	.1484	.1608	.1535	.1218	.1389	.1635	.1635	.1635	.1635
S_1	.0683	.0805	.0718	.1206	.1182	.1196	.1059	.1029	.1045	.1054	.1264	.0903	.0790
S_2	.9317	.9195	.9282	.8794	.8818	.8804	.8941	.8971	.8955	.8946	.8736	.9097	.9210
T_1	.6250	.4741	.5817	.5668	.5418	.5562	.6041	.4575	.5343	.5445	.5445	.5445	.5445
T_2	.3750	.5259	.4183	.4332	.4582	.4438	.3959	.5425	.4657	.4555	.4555	.4555	.4555

TABLE 50

Observed and Expected Frequencies, Chi-Square Contributions, and Total Chi-Squares for each Section of the Corpus for the Categorial Grammar for Noun Phrases

GINN PRE-PRIMER

OBSERV.	EXPECT.	CHI**2	SOURCE
230	230.0	.0	P
254	254.0	.0	G
76	70.6	.4	N
23	31.1	2.1	A+N
8	5.7	.9	A+A+N
121	117.7	.1	T+N
42	51.8	1.8	T+A+N
17	9.5	5.9	T+A+A+N
1	.6		A+A+A+N
1	1.6		RESIDUAL
772	772.0	11.3	TOTAL
		3	DEGREES OF FREEDOM

SCOTT-FORESMAN PRE-PRIMER

OBSERV.	EXPECT.	CHI**2	SOURCE
424	424.0	.0	P
132	132.0	.0	G
33	36.9	.4	N
24	19.4	1.1	A+N
4	4.2		A+A+N
36	33.2	.2	T+N
14	17.5	.7	T+A+N
5	3.8		T+A+A+N
9	8.1	.1	EXPECTED FREQ. LESS THAN 5.0
0	.5		A+A+A+N
0	1.0		RESIDUAL
672	672.0	2.5	TOTAL
		2	DEGREES OF FREEDOM

TABLE 50 (continued)

```
                PRE-PRIMERS COMBINED

    OBSERV.   EXPECT.   CHI**2  SOURCE

       654     654.0       .0  P
       386     386.0       .0  G
       109     108.1       .0  N
        47      50.2       .2  A+N
        12       9.7       .5  A+A+N
       157     150.3       .3  T+N
        56      69.7      2.7  T+A+N
        22      13.5      5.4  T+A+A+N
         1       1.0           A+A+A+N

         1       2.5           RESIDUAL

      1444    1444.0      9.1  TOTAL

                            3  DEGREES OF FREEDOM
```

```
                GINN PRIMER

    OBSERV.   EXPECT.   CHI**2  SOURCE

       727     727.0       .0  P
       286     286.0       .0  G
        86     130.4     15.1  N
       123     107.3      2.3  A+N
        56      36.8     10.0  A+A+N
       227     170.7     18.6  T+N
        99     140.4     12.2  T+A+N
        43      48.1       .5  T+A+A+N
        17       6.7     15.7  A+A+A+N

         0      10.5     10.5  RESIDUAL

      1664    1664.0     85.0  TOTAL

                            5  DEGREES OF FREEDOM
```

TABLE 50 (continued)

```
               SCOTT-FORESMAN PRIMER

OBSERV.   EXPECT.   CHI**2  SOURCE

  784      784.0       .0   P
  220      220.0       .0   G
   63      103.0     15.5   N
  110       82.8      8.9   A+N
   43       27.7      8.4   A+A+N
  153      121.8      8.0   T+N
   78       97.9      4.1   T+A+N
   28       32.8       .7   T+A+A+N
    3        5.0            A+A+A+N

    3       12.0      6.7   RESIDUAL

 1482     1482.0     52.3   TOTAL

                     4      DEGREES OF FREEDOM
```

```
               PRIMERS COMBINED

OBSERV.   EXPECT.   CHI**2  SOURCE

 1511     1511.0       .0   P
  506      506.0       .0   G
  149      233.3     30.5   N
  233      190.1      9.7   A+N
   99       64.6     18.4   A+A+N
  380      292.5     26.2   T+N
  177      238.3     15.8   T+A+N
   71       80.9      1.2   T+A+A+N
   20       11.7      5.9   A+A+A+N


    0       17.5     17.5   RESIDUAL

 3146     3146.0    123.1   TOTAL

                     5      DEGREES OF FREEDOM
```

TABLE 50 (continued)

```
                    GINN READER

OBSERV.  EXPECT.  CHI**2  SOURCE

  1143    1143.0      .0  P
   473     473.0      .0  G
   215     296.3    22.3  N
   238     210.6     3.6  A+N
   103      62.4    26.5  A+A+N
   556     452.1    23.9  T+N
   243     321.3    19.1  T+A+N
    86      95.2      .9  T+A+A+N
    24       9.9    20.3  A+A+A+N

     0      17.4    17.4  RESIDUAL

  3081    3081.0   133.9  TOTAL

                       5  DEGREES OF FREEDOM
```

```
              SCOTT-FORESMAN READER

OBSERV.  EXPECT.  CHI**2  SOURCE

   997     997.0      .0  P
   323     323.0      .0  G
   239     376.3    50.1  N
   370     259.0    47.5  A+N
    97      74.3     6.9  A+A+N
   430     317.4    40.0  T+N
   148     218.5    22.7  T+A+N
    31      62.7    16.0  T+A+A+N
    16      11.4     1.9  A+A+A+N

     0      11.4    11.4  RESIDUAL

  2651    2651.0   196.6  TOTAL

                       5  DEGREES OF FREEDOM
```

TABLE 50 (continued)

READERS COMBINED

OBSERV.	EXPECT.	CHI**2	SOURCE
2140	2140.0	.0	P
796	796.0	.0	G
454	671.5	70.4	N
608	470.1	40.4	A+N
200	137.1	28.8	A+A+N
986	770.5	60.3	T+N
391	539.4	40.8	T+A+N
117	157.4	10.4	T+A+A+N
40	21.3	16.3	A+A+A+N
0	28.6	28.6	RESIDUAL
5732	5732.0	296.1	TOTAL
		5	DEGREES OF FREEDOM

ALL COMBINED

OBSERV.	EXPECT.	CHI**2	SOURCE
4305	4305.0	.0	P
1688	1688.0	.0	G
712	1011.0	88.4	N
888	714.5	42.1	A+N
311	210.4	48.1	A+A+N
1523	1208.4	81.9	T+N
624	854.0	61.9	T+A+N
210	251.5	6.8	T+A+A+N
61	33.0	23.7	A+A+A+N
0	46.2	46.2	RESIDUAL
10322	10322	399.3	TOTAL
		5	DEGREES OF FREEDOM

TABLE 50 (continued)

```
            ALL COMBINED (N=5)

OBSERV.   EXPECT.   CHI**2  SOURCE

 4305     4305.0       .0   P
 1688     1688.0       .0   G
  712     1003.1     84.5   N
  888      726.0     36.1   A+N
  311      210.2     48.4   A+A+N
 1523     1198.9     87.6   T+N
  624      867.7     68.5   T+A+N
  210      251.2      6.8   T+A+A+N
   61       30.4     30.7   A+A+A+N

    0       41.4     41.4   RESIDUAL

10322    10322      403.9   TOTAL

                      5     DEGREES OF FREEDOM
```

```
            ALL COMBINED (N=7)

OBSERV.   EXPECT.   CHI**2  SOURCE

 4305     4305.0       .0   P
 1688     1688.0       .0   G
  712     1016.5     91.2   N
  888      706.5     46.6   A+N
  311      210.5     48.0   A+A+N
 1523     1215.0     78.1   T+N
  624      844.4     57.5   T+A+N
  210      251.5      6.9   T+A+A+N
   61       34.8     19.7   A+A+A+N

    0       49.6     49.6   RESIDUAL

10322    10322      397.7   TOTAL

                      5     DEGREES OF FREEDOM
```

TABLE 50 (continued)

```
              ALL COMBINED (N=8)

     OBSERV.  EXPECT.  CHI**2  SOURCE

      4305    4305.0       .0  P
      1688    1688.0       .0  G
       712    1020.6     93.3  N
       888     700.6     50.1  A+N
       311     210.4     48.1  A+A+N
      1523    1219.9     75.3  T+N
       624     837.4     54.4  T+A+N
       210     251.5      6.9  T+A+A+N
        61      36.1     17.1  A+A+A+N

         0      52.2     52.2  RESIDUAL

     10322   10322      397.5  TOTAL

                           5   DEGREES OF FREEDOM
```

TABLE 51

Comparison of Total Chi-Squares for the Phrase-Structure and Categorial Grammars for Noun Phrases

		Phrase-Structure Grammar		Categorial Grammar	
Text	No. of Phrases Accounted For	Total Chi-square	Degrees of Freedom	Total Chi-square	Degrees of Freedom
Ginn Pre-Primer	772	.5	1	11.3	3
Scott-Foresman Pre-Primer	672	2.3	0	2.5	2
Pre-Primers Combined	1444	1.3	1	9.1	3
Ginn Primer	1664	52.2	2	85.0	5
Scott-Foresman Primer	1482	42.6	1	52.3	4
Primers Combined	3146	95.3	2	125.1	5
Ginn Reader	3081	81.5	2	133.9	5
Scott-Foresman Reader	2651	177.5	2	196.6	5
Readers Combined	5732	247.6	2	296.1	5
All Combined	10322	316.8	2	399.3	5

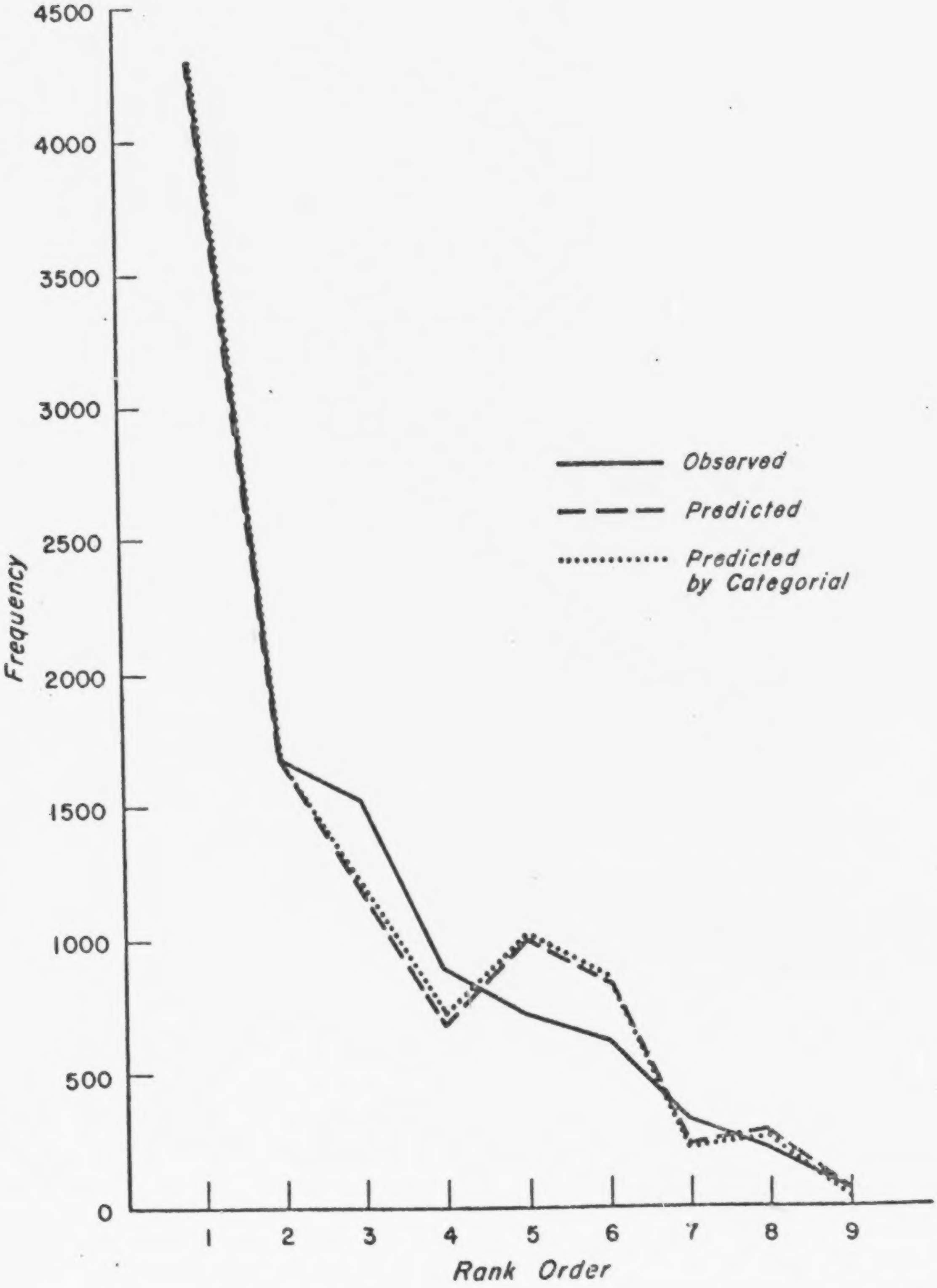

Fig. 7. Comparison of observed and predicted frequencies for phrase-structure and categorial grammars for noun phrases (entire corpus).

Identifiability
of
Transformational
Grammars

by

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0 This paper extends a formal theory of language learning to transformational components. Learning procedures which are psychologically more suggestive than those previously studied are shown to yield positive results under formally specified conditions. Part 1 introduces the general class of problems to be studied; part 2 states and discusses various possible assumptions; and part 3 is a formal proof for a particular case of interest.

1 Introduction

A formal theory of language learning has been proposed (Gold, 1967), in which the learner is presented with a sequence of data and must guess, after each datum, what language of a given class he is encountering. He is never told whether his guess is correct but if his guessing sequence converges, he is said to succeed. More specifically, if his procedure must in all cases lead to a correct guess sooner or later, and then stay correct, then the procedure "identifies-in-the-limit" that class of languages.

Note that the problem facing the learner (child, program-plus-computer, or Turing machine) is to select a language from a class of languages. If the class consists of a single language, then the learner can, trivially, succeed instantly simply by always guessing that language, even though the language itself is exceedingly complex. Thus it is meaningless to ask whether a particular language is identifiable; we ask only about classes.

If the data are only the correct sentences, then Gold shows that there is no learning procedure for any of the classes of languages commonly studied in connection with natural language. That is, the context-sensitive, context-free and even the finite-state grammars all of which have been proposed as models of the base for transformational grammar correspond to language classes which are not learnable in this sense. On the other hand, for the so-called "informant" presentation scheme which also includes all possible instances of non-sentences, labeled as such, the above classes and even the class of primitive recursive languages is identifiable in the limit.

In view of the prominent role of transformational grammar in current linguistic research we have investigated the identifiability of a certain class of transformational mappings. It is necessary in this context to speak of mappings, not languages, in order to indicate precisely what the learner is required to accomplish. If we ask only that he select a language from a class, then we must be satisfied if he gives us a correct representation of the set of surface strings, with no indication of which of them goes with which base phrase-marker. For example, the learner might provide a "surface grammar" which generates all and only the surface strings. To accept such a result is to ignore a tenet of transformational theory that the mapping of particular deep structures to particular utterances is part of linguistic competence.

In this connection we introduce the notion of moderate equivalence. Two transformational components are moderately equivalent with respect to a given base grammar iff for each phrase-marker of the base the two respective derived structures (obtained by transforming the base phrase-marker with the two components, respectively) have the same terminal string. This definition differs from strong equivalence in that the two derived pm's need not be identical, and it differs from weak equivalence in that the mapping and not just the surface language is preserved, as discussed in the preceding paragraph.

To select the correct member of a class of T-mappings it is sufficient to specify one member of the set of moderately equivalent T-components which accomplish that mapping, just as, in the case of, say, cfl's it is sufficient to specify one of the weakly equivalent cfg's that generate it. We shall deal only with procedures in which the learner guesses at the mapping by guessing a T-component, and therefore use the terms grammar-class and mapping-class interchangeably.

No mention has been made of the learning of the base. It is of course possible to seek conditions under which both the base and the T-component can be found, but attention is here restricted to the T-component. That is, we make the assumption, discussed in the next section, that the base is known to the learner from the outset.

Let T be a class of transformational mappings, I a scheme of information presentation, C a criterion convergence or learning, and P a learning procedure. We seek quadruples <T, I, C, P> such that T is learnable in sense C by applying P to information about T of form I.

There is a vast array of positive and negative results which can be obtained along these lines, some of which are trivial and others of which are nontrivial but uninteresting. Interestingness of the results depends on adequacy of T as a model of natural language; the strength of C; and the plausibility of P and I, judged by implications for human development, simplicity, efficiency, or as a starting point, subjective reasonableness.

P is of particular interest since it can be regarded as a theory of learning, though it is premature to seriously suggest any of the P's looked at so far as such. Certain results can be obtained using enumeration procedures, but if taken as models of human language learning, they have bizarre implications, discussed in the next section.

2 Discussion of Assumptions

In the preceding section we noted that our interest would be in quadruples consisting of a grammar (or mapping) class, a presentation scheme, a learning criterion and a procedure. The results cited from Gold show that learnability depends crucially on the data presented as well as on language class. We note in 2.2 below that even a change in the kind of data sequence, with no change in the class of data can have a striking effect on what procedure may be used.* Such differences in procedure are not of importance in proofs of Turing machine capability, but may bear importantly on the plausibility of a model for human language acquisition. Learnability may also hinge on what criteria are used. Some preliminary studies in that area have been made by Feldman (1969), but it is not one of our principal concerns here. The four subsections which follow deal respectively with the four aspects mentioned in the first sentence of this section.

2.1 The Class of Transformational Grammar

The base grammar is taken from the class, called eCFG, of context-free grammars in which the start symbol, S, is an essential recursive element. That is, recursion occurs only through S, so that any two occurences of a non-terminal symbol on the same path of a base phrase-marker must be separated by an S.

---

* Gold also shows such a result, but the restriction he places on the data sequence is severe and the result is therefore of diminished interest. Gold recognizes this in referring to that presentation scheme as "anomalous text." When citing Gold's results we implicitly exclude this case.

The transformational component is first applied to sub-trees dominated by bottom-most S's in the base phrase-marker. Other S-dominated sub-trees are transformed only after all those within them have been transformed. A singulary transformation is one which refers only to nodes dominated by no S other than the root-S of the subtree being transformed. A binary transformation may refer to nodes dominated by at most one S other than that root S, in the subtree being transformed. Only singulary and binary transformations are allowed. When a binary transformation takes nodes out from under an S those nodes must, under certain conditions, be marked as ineligible for future transforming. The particular conditions are motivated by specific studies of English and are also used in the proof of identifiability.

All transformations are obligatory. Only one transformation may apply at any given level. That is, in order to transform an S-dominated subtree, check whether there is some proper analysis of that subtree, consisting only of currently eligible nodes, which fits the structural description of one of the transformations in the T-component. If so then the structural change indicated by the transformation is carried out; if not, no change is made. In the principal theorem it is assumed that there will never be two transformation which both are applicable at the same point and which give conflicting results. The same result can also be shown in the case where there is a precedence ordering over transformations so that whichever applicable transformation comes earlier in the ordering is the one which is used. A slightly more complex learning procedure is used in the latter case.

Sequential application of more than one transformation at the same level is not allowed. Formally this requirement is a restriction on the class of T-components since it has been shown (Ginsburg and Partee, 1969) that there are sequences of transformations which achieve structural changes unattainable by a single transformation. Still one might put forth an empirical claim that such situations do not occur in natural language. But if we are going to bring in linguistic considerations then it must be admitted that descriptions of natural language will be complicated enormously by this assumption. For example, suppose in some language there is a passive transformation, T_p, and a question transformation, T_q. Further imagine that there are passive questions which can be formulated by applying both T_p and T_q successively at the same level. Although it may be formally possible to create a new transformation by composition of T_p and T_q, such a move would be counter to the aim of economy of description. In fact, it has been argued that passivization itself is appropriately described as a composite of two simpler transformations (Chomsky, 1968).

Some parts of the foregoing description of the class of grammars are based on properties suggested by transformational linguists in other contexts; some are not. Of particular interest are the restrictions on node-raising noted above and made precise in section 3. These have not been mentioned in previous work but appear to be true at least for English. If our observation is substantiated it will mean that the formal study of acquisition has provided an insight into the acquired language structure.

2.2 The Information Presentation Scheme

Learning transformational grammar appears intuitively to be a formidable task, one requiring a rich information source. Moreover, to restrict the learner to working only with surface strings or even with sentential and non-sentential strings distinctively labeled (Gold's "informant") is to deprive him of resources available to children and linguists. The fact that a child's first words refer to the objects and scenarios ("bye-bye", "allgone") of his experience is ample proof that he attends not merely to utterance but to meaning as well. As for the linguist, there is a reason why the Rosetta Stone was such a big find. That is, even if one is equipped with distributional analysis, it is helpful to have meaning available.

On the formal side, since the class of transformational grammars includes the class of fsg's, identifiability from surface strings alone is impossible. Furthermore, Peters and Ritchie (1970) have shown that the addition of a certain class of transformations to even a simple finite state base yields the power of a Turing machine. This result, together with Gold's, shows that this class of T-grammars is not learnable even from an informant. It is thus necessary either to decrease the power of T-component or to increase the richness of the information source, or both, if T-grammar is to be learnable according to our criteria. We have done both: the restrictions on the T-component* are described in the preceding subsection; here we describe the enriched information.

We assume that the base grammar is known to the learner at the outset. The universal base hypothesis will not be defended here; we only note that it is consistent with our assumption. Another interpretation of this assumption might be that although the base is not present at the start, a particular transformation is learned only after the related portion of the base is learned. Certainly kernel sentences, which are "closer" to the base, seem to be learned before non-kernel sentences.

The information presentation consists of a sequence of ordered pairs. The first element of each pair is a base phrase-marker, while the second is a surface string. If one believes in generative semantics, then such information is meaning - plus - utterance. It seems doubtful that the child receives as input the precise meaning of each sentence as it is spoken, independently of the utterance.

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* Even for our restricted version of T-grammar, the associated language class is not identifiable in the limit from surface strings (Wexler and Hamburger, 1970).

We may alternatively suppose that the child learns from responses to his own output. To make this notion clearer, suppose that in order to communicate a child first formulates an idea and then translates it into an utterance. If the idea constitutes a base phrase-marker and the translation is accomplished by using a not-yet perfect transformational component, then the resulting utterance may be close enough to the correct one (which would have resulted from using a correct T-component) so that an adult can figure out what is intended and supply the correct utterance. This adult utterance would then be the second member of the ordered pair making up a datum; the first being the base pm.

A possible objection to the idea of correction by adults is the contention by observers of children that corrections are ignored. Evidence cited for this position is typically that children repeat errors soon after being corrected. This objection can be answered in several ways. If the error is the result of using a wrong transformation (arising from, say, a previous over-generalization) then our procedure can result in the rejection of any transformation used. If the child picks the wrong one to throw out, then he will still err on that sentence, though in a different way. Also, unless the repetition is a sentence identical to the first, the child may have acted on the correction but done so by hypothesizing a transformation of too limited generality. Thus "repeated errors" may not really be repetitious from the viewpoint of the childs' developing grammar.

A more fundamental objection to the idea of correction by adults is that, if taken seriously, it requires that a theory of correction be precisely stated. That is, we must specify just how it is that adults convert a child-sentence into the appropriate adult-sentence. In a way this proposal converts the problem of how a child learns adult language into the complementary problem of how an adult learns a child language. We may escape this circular reasoning by supposing that the latter problem, which is easier than the former, is done at least partly by the "input" method described above. In this way, adult and child would share the computational burden.

The presentation scheme consists of choosing a datum pair from the set of all correct datum pairs according to a fixed probability distribution. Each pair has a fixed non-zero probability of occurrence regardless of how often it has appeared previously. This kind of scheme appears to run counter to the notion of corrected output, discussed above, in which the learner determines what datum comes next by picking a base phrase-marker. However, if the learner requires a particular datum, he can use the strategy of waiting until it appears again. For each datum the probability of this strategy failing forever is zero. Conversely if he is allowed to determine the order of presentation he can choose to do so randomly.

A probabilistic information source insures that any particular datum will always appear again, so it is unnecessary to save all previous data. This is certainly a desirable consequence for a model of human learning. Although a child may retain some data in raw form for awhile, it would certainly be unjustified to require retention of all data throughout learning.

2.3 Criterion

Probabilistic presentation requires a probabilistic criterion of learning. A language class is identifiable in the-limit-with-probability-1 with respect to a probabilistic presentation scheme if there exists a learning procedure such that for any member of the class there is a subset, of measure 1, of the set of presentation sequences, for which the procedure identifies-in-the-limit the language.

2.4 Procedure

2.4.1 Comparison with Enumeration

The learning procedure introduced here differs from enumeration in at least three ways, all of which are related to its plausibility as a model of human learning. First it does not require storage of all previous date; this aspect was discussed at the end of 2.2.

Second and most importantly, it does not engage in the wholesale reject of T-components. With the advent of each new datum, there is a computation based solely on that datum together with the currently hypothesized set of transformations. The result of that computation is to reject a single transformation from the hypothesized set, to add a new one to it or to leave the set unaltered. ("New" here simply means "not currently a member;" the added transformation may have been hypothesized and discarded previously). The procedure actually specifies several candidates for hypothesization (adding to the currently guessed set) and several for rejection, the choice among alternatives to be made probabilistically. Since the probabilities can be assigned in a variety of ways we actually have a family of procedures; so different allowable methods of assigning probabilities may be thought of as heuristics, any of which will yield identifiability, some being more efficient than others in certain situations. Whatever the probabilistic scheme, we emphasize that a datum can affect only a single rule, not as with enumeration, reject an entire component only to examine a new component chosen arbitrarily from an a priori enumeration scheme unrelated to any of the data presented.

A third objection to enumeration which is overcome by the procedure used here has to do with the discovery of inserted morphemes. A learner, even if he has the base grammar, has no knowledge of the set of inserted morphemes at the outset. Thus he cannot actually construct an enumeration of T-components unless he makes some assumption about what that set is. Since the set differs for different natural languages, it is not reasonable to suppose that knowledge of the exact set is part of the learner's initial information.

Two alternative assumptions suggest themselves, both of them unsatisfactory though for different reasons. First we might assume initial knowledge of the class of all morphemes which could possibly be inserted in any language. This would amount to knowledge of a universal discrete phonological alphabet, assuming one exists. The enumeration would then include all components consisting of transformations calling for insertion in all possible ways of all possible combinations of morphemes, each morpheme consisting of any possible sequence of phonemes taken from the universal phonological alphabet. The reader may judge the plausibility of this procedure for himself.

Another possible solution to the morpheme discovery problem for an enumeration procedure is to begin by using an enumeration with the set of inserted morphemes assumed to be empty. Thereafter, each time a new morpheme is encountered in the data, that morpheme is added to the set of inserted morphemes and a new enumeration of T-components is begun with this augmented morpheme class assumed to be correct. It can be seen that this procedure makes no use of any information gleaned from data prior to the presentation of the last morpheme, except to extract the correct set of morphemes. (Note that its computation load during this period is no lighter than normal since it never knows whether the period is over).

The procedure used here incorporates new morphemes into transformations in the same way that it handles permutation, deletion and copying. Any transformation which is hypothesized must be applicable to the current datum, and we will see that eventually data appear for which some possible hypotheses insert that morpheme. The identifiability proof of course shows more than that morphemes find their way into the T-component. But that aspect is emphasized in this connection to compare our method to enumeration. The point is that we handle morphemes in a straightforward integrated part of the procedure, without making a special list for them and re-starting the procedure each time a new one appears.

2.4.2 Description of Procedure

The procedure operates on each successive datum to produce a set of transformations which may be hypothesized and a set which may be rejected. It then chooses one randomly from among them and adds it to or removes it from the current component. The "current component", which constitutes the current guess, is the set of all current transformations, together with a fixed (a priori correct) set of meta-rules concerning application.

The base phrase-marker which constitutes the first half of each datum is transformed according to the current T-component. If the resulting derived phrase-marker has a terminal string identical to the correct surface string given as the second half of the input datum, then no change is made in the current component. This insures that when the correct mapping (that is, the correct T-component or any component moderately equivalent to it) is found, no further changes will be made. It will then be necessary only to show that the expected value of the time at which the correct mapping is found is finite.

If on the other hand the current component assigns to the input base phrase-marker a wrong surface string or if the component is ambiguous* in its treatment of that phrase-marker, then the operation of the component up to the point of error discovery is examined. Error in this connection is said to be discovered at the lowest point in the pm where ambiguous application is encountered or else, in the case of a wrong derived string, at the top of the phrase-marker. Each application (up to that point) of the current component to an S-dominated subtree consists either of no transforming or else the application of a single transformation. Any transformation which has been applied is a candidate for rejection. For each S-dominated subtree where no transformation was applied, create candidate hypotheses by using the hypothesizer H(p,t) where p is that S-dominated subteee, t is a terminal string and H(p,t) consists of all possible transformations which transform p into a phrase-marker with terminal string t. The terminal string t to be used is the correct surface string, s, given as part of input, whenever p is the subtree which is the entire derived phrase-marker (that is when working at the top level). Otherwise, a "string-preserving" transformation is hypothesized; that is, t is taken to be the terminal string of p.

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* This is not the allowable ambiguity of many phrase-markers mapping to a single surface string, but rather its converse, which for obligatory T's is not allowable.

The particular specifications of this procedure, though reasonable, are not obvious or more natural than many others one could envision. They are not motivated by any direct attempt to model what might be human procedures. What is claimed for them, rather, is that taken together they achieve formal learning without exhibiting the undesirable characteristics cited for enumeration.

3.1 Outline of Proof

The various possible current components are regarded as states of a Markov chain and the various probabilities of moving from one state to another are investigated with a view to putting lower bounds on some of them. It was noted earlier that once an acceptable component (one moderately equivalent to the correct one) becomes the current component it is always guessed thereafter. In the proof this is re-phrased as the statement that any acceptable component corresponds to an absorbing state. It is then shown that there is a path from any possible current component to some acceptable component, such that the path is shorter than some pre-assigned upper bound and such that each step of the path has probability greater than some pre-assigned lower bound. We now state this formally. Let Q be the set of states corresponding to possible current components. Let A be the set of states corresponding to acceptable components. Then

$$(\exists p)\ (\exists k)\ (\forall q \in Q)\ (\exists a \in A)\ (\exists r \leq k)$$

$$(\exists q_1, q_2, \ldots, q_{r-1} \in Q)\ (p(q_{i+1} | q_i) \geq p,$$

$$\text{for } 0 \leq i \leq r-1, \text{ where } q_0 = q \text{ and } q_r = a).$$

Not all sets of allowable transformations constitute possible current components. According to the meta-rules we are imposing on transformational components, if two transformations have the same structural description then either there is a datum for which they conflict or else one of them is superfluous. It is thus a desirable* trait of the procedure used here that it can never have two such transformations. This follows from the fact that hypothesizations are always based on (partially transformed) phrase-markers to which no current transformation applies.

The use of only singulary and binary transformations together with the restrictions on raising results in a bound on the number of operationally distinguishable proper analyses of phrase-markers even though there are infinitely many base- and derived- phrase-markers. It follows that there is also a bound on the number of structural descriptions which fit these proper analyses. This latter fact together with the considerations of the preceding paragraph gives a bound on the size of the current component.

A crucial and complicated piece of the argument is to show that any component which makes some mistake must make one on some datum of degree less than some pre-assigned value. The details of the proof of this point appear to provide no particular linguistic insight. We conclude from it that any non-acceptable component will be revealed as such by one of a finite set of data, hence with lower-bounded probability. That finite set of data is the set of all data with base phrase-marker of degree less than a particular pre-assigned value which is determined solely by the given base component.

We have been speaking up to this point of acceptable components. At this point we arbitrarily single out some particular acceptable component and henceforth[*] call it the "correct component." At an arbitrary point in time let the current component be any possible non-acceptable component. Then, as asserted above, there is a lower bound on the probability that the next datum is both incompatible with the current component and of degree less than some upper bound.

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* "desirable" with respect to the class of T-components as defined.

From boundedness of degree it is shown that the number of transformations which the learning procedure puts forth as candidates for rejection or hypothesization is bounded. Among the candidates for rejection and hypothesization there may be one (or more) which is a candidate to move the "right" way with respect to the component we have singled out as "correct." That is, perhaps (a) one of the candidates for rejection is not in the correct component or (b) one of the candidates for hypothesization is in the correct component. Working up from the bottom of the phrase-marker, the first[**] S-dominated sub-phrase-marker which is handled incorrectly gives rise to the first maistaken structure (partially-derived phrase-marker). On one hand if this first mistaken structure arrises from application of a transformation then that transformation is a candidate for rejection (so are all other transformations used on the datum). On the other hand if the first mistaken structure is a result omission, there being no applicable transformation even though the correct component contains an applicable transformation, T, then there are two possibilities: either T is string-preserving with respect to the particular sub-phrase-marker- or it is not.

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[*] We could just as well have singled it out at the outset, by phrasing the problem as one of finding either the correct component or one moderately equivalent to it, instead of saying we would look for a mapping. The locutions are equivalent.

[**] If there are mistakes in several non-overlapping sub-phrase-markers then none is uniquely "first" but any of them will do for this argument.

If it is, then T is a candidate hypothesis, according to the procedure; if not then there is another datum, of lower degree than the one being considered (hence also with probability exceeding the lower bound), which is also incompatible with the current component. This lower-degree datum is the one whose base phrase-marker is formed from that of the original datum (which we have been dealing with up to this point) by taking the S-node being considered together with all the nodes it dominates. This new datum is handled correctly by the current component right up to but not including the top cycle, at which point the correct component applies T, thereby altering the terminal string whereas the current component has no applicable transformation and hence must give an incorrect surface string. The hypothesization operator is applied to give as candidate hypotheses all transformations which give the same string that T gives at this point. T must be one of these, so T is a candidate hypothesis. As noted above, the number of all candidate alterations of both types will be shown bounded. Thus if candidates are equi-probable,[*] there is a lower bound for their individual probabilities.

In summary to this point, there are lower bounds on the following probabilities: (a) that a datum will occur which reveals the unacceptability of the current component (if indeed it is unacceptable), (b) that any particular alteration specified as a possibility by the procedure will be made, and (c) that for some datum as described in (a) some alteration in the right direction will be among the specified alterations. Taken together these imply a lower bound on the probability that the next datum results in a step toward the designated correct component.

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[*] It is not necessary to assume equi-probability.

As noted earlier, there is a bound on the size of current components. At an arbitrary point in time let the current component be C and let the fixed correct component be C^t (t for "true"). What we have argued is that, with lower-bounded probability either a member of $C^t - C$ (set-difference) is hypothesized or a member of $C - C^t$ is rejected. This continues to be the case until either C^t or some other acceptable component is reached. The time to reach C^t in the event that no other acceptable component is reached first is equal to the size of $(C^t - C) \cup (C - C^t)$, and is therefore bounded by the sum of the size of C^t and the bound on the size of possible current components. The statement (*) has thus been established and it follows that we can put a bound on the expected value of the total time taken to "converge," that is, reach an acceptable state. Finally, the probability of identifiability-in-the-limit must be 1 for if there were non-zero probability of non-identifiability then the expected "convergence" time would be infinite.

October 30, 1970

TO: Members of the Workshop in Grammar and Semantics

The following list of references was omitted from the segment of the Hamburger-Wexler paper sent to you last week. The Gold paper is most relevant.

Chomsky, N., "Remarks on Nominalization", MIT ditto, 1968 and forthcoming in Jacob and Rosenbaum, *Readings in Transformational Grammar*.

Feldman, J., several papers, some co-authored, available through Dept. of Computer Science, Stanford

Ginsburg, S., and Partee, B., "A Mathematical Model of Transformational Grammars", *Information and Control*, Vol. 15, No. 4, Oct., 1969. p. 297

Gold, E. M., "Language Identification in the Limit", *Information and Control*, Vol. 10, No. 5, May 1967. p. 447.

Jaakko Hintikka

Grammar and Logic:
Some Borderline Problems

Recently it has been claimed by generative semanticists that "the rules of grammar are identical to the rules relating surface forms to their corresponding logical forms" (G. Lakoff, 1970, p. 11). Even apart from such sweeping claims, a certain convergence of interest is unmistakable among logically minded linguists and linguistically minded logicians. Examples are offered by much of the recent work of several participants of the present meeting.

Much of this convergence of interest has taken place in the area which logicians know as modal logic (in the wide sense of the word in which it includes, e.g., the logic of propositional attitudes) and in the study of the behavior of these modal terms in ordinary language. Thus Lakoff writes: "It seems to me that recent developments in modal logic, together with recent developments in linguistics, make the serious study of natural logic possible" (op. cit., p. 124), "natural logic" being for Lakoff tantamount to "the empirical study of the nature of human language and human reasoning" (op. cit., p. 126).

It seems to me that in modal logic and its applications we indeed have a promising field for the interaction of logical and linguistic viewpoints. A major reason for this promise is precisely the one Lakoff mentions, viz. recent developments in modal logic, especially the development of a satisfactory semantical theory of modality (in logicians' sense of semantics, of course). At the same time, it seems to me that much remains to be done and even changed in this area. Some of the logicians' insights have apparently been partly overlooked by linguists. Some of these insights may even serve to disprove certain claims by linguists or at least bring to light major difficulties in them. In particular, in this direction we may perhaps discover serious difficulties in some of the more sweeping theses of such linguists as Lakoff.

In the present paper, I shall try to illustrate these points by discussing somewhat tentatively a couple of problems arising from those aspects of natural languages which correspond--in some rough sense--to the phenomera modal logicians have studied.

First, it seems to me that the most germane idea in the last fifteen years' work in modal logic, viz. the use of "possible worlds" to elucidate the semantics of modality, has not been brought to bear by the linguists on their problems in its full strength. This idea is as simple as it is fruitful.[1] According to it, to understand a modal notion is to understand a certain relation--we may call it an alternativeness relation--on a set of possible worlds. In the case of propositional attitudes, this relation is relative to a person. For instance, in the case of necessity, the alternatives to a world W may be thought of as those possible worlds which could be realized instead of W. Then a necessary truth in W means truth simpliciter in all these alternatives. Likewise, alternatives to W arising in considering what a person a believes--we may call them doxastic a-alternatives to W--are the possible worlds compatible with everything that a believes in W. Then it is true in W that a believes that p if and only if p is true in all these alternatives.[2]

These examples show how we may obtain truth-conditions for modal statements. Putting the main point very briefly and somewhat crudely, by stepping from a world to its alternatives the truth-conditions of modal statements can be reduced to truth-conditions of non-modal statements. And in view of the importance of such truth-conditions it is only to be expected that on their basis we can easily explicate a good deal of the behavior of modal notions.

The advantages of this approach are nowhere more clearly in evidence than in dealing with questions of reference. If all non-redundant use of modal notions entails the consideration, however tacit, of several possible worlds, then for each singular term--linguistics might prefer speaking of nouns and noun phrases here--we *ipso facto* have to consider its several references in these different worlds. This shows at once that there is nothing strange in the failure of such so-called laws of logic as the substitutivity of identity in modal contexts. Clearly two singular terms "*a*", "*b*" which in the actual world pick out the same individual and hence make the identity "a = b" true *de facto* may fail to do so in alternative worlds, and hence fail to admit of interchange *salva veritate* in a context containing modal terms.

Likewise, the law known as existential generalization can only be expected to fail, for a singular term "*a*" may very well make a statement--say "$F(a)$"--true and yet fail to allow any foothold for maintaining that "$(Ex)\ F(x)$" is true, i.e., that "$F(x)$" is true of some definite individual x. This may happen when "*a*" picks out different individuals in the different possible worlds which we are considering in "$F(x)$", assuming that it contains non-redundant modal notions.

All this is old hat to most logicians and to some linguists. It can all be given an explicit logico-semantical formulation, which nevertheless would neither add much to nor detract much from the central theoretical ideas just adumbrated.

An informal remark might illustrate further the naturalness of this approach. Some of those linguists who have in fact seen the advantages of the idea of considering several "possible worlds" have occasionally tried to get away with a simpler scheme. Instead of considering, say, all the possible worlds compatible with what *a* believes, they have tried to consider *a*'s "belief world", that is, the world as *a* believes it to be. The only thing wrong here is that unless *a* is supremely opinionated, his beliefs do not specify completely any particular world, but rather a disjunction (as it were--usually it would have to be infinite) of descriptions of several such worlds. To specify "the world as it is believed by *a* to be" is not to describe any one possible world, but rather a set of possible worlds. However, these are precisely the doxastic *a*-alternatives to the actual world. Hence to specify these *is* to specify what *a* (actually) believes.

Now assuming that our possible-worlds semantics is at all like the true story of the "logical form" of our modal statements, some interesting conclusions are immediately suggested by it.

For instance, consider the role of what has been called by grammarians coreferentiality. It is exemplified by the dependence of the admissibility of a derivation of

(1) John lost *a black pen* yesterday and Bill found *it* today

from

(2) John lost a black pen yesterday and Bill found a black pen today,

possibly by way of

(3) John lost a black pen yesterday and Bill found the black pen today.

(I am stealing these examples, and others, from Partee (1970).) Consideration of more complicated examples already led Postal (1968) to realize that the reference (or co-reference) in question cannot be one that obtains in the actual world. However, it is not very easy to tell precisely what else it could be. For instance, it is sometimes said that what counts here is some kind of identity relative to the "speaker's mental picture of the world". Apart from the vagueness of such characterizations, this particular formulation is demonstrably insufficient, for what matters is in some cases the "mental picture"--whatever it may look like--, not of the speaker, but of some other person. A simple case in point is offered by

(4) John lost a black pen yesterday and Bill believes that he has
found it today.

One reason why (4) cannot be dealt with in terms of coreferentiality in the actual world or in the kind of world the speaker is assuming is that the speaker may know that Bill is mistaken in his belief and has not found John's pen--and perhaps has not found anything at all.

Yet all these troubles are predictable--and solvable--as soon as it is acknowledged that in modal contexts more than one possible world is inevitably at issue. For then we cannot even speak meaningfully of coreferentiality except relative to the specification of some particular possible world or class of possible worlds. For instance, what makes the difference in (4) is the identity (or the coreferentiality of the corresponding terms) of the black pen John lost yesterday with the one Bill has found today in Bill's doxastic alternatives to the world (4) is dealing with. By systematically using the possible-worlds idea, the theory of coreferentiality can be freed from the looseness of "mental pictures" and other similar largely metaphorical paraphernalia.

Likewise, we can at once appreciate a fact which prima facie can be fitted into the coreferentiality framework only by mild violence, viz. the fact that "coreferentiality may hold independently of referentiality". By this paradoxical-sounding statement I mean such things as e.g., the fact that we can say

(5) John wants to catch a fish and eat it for supper.

even when John is not assumed to be angling for any particular piece of seafood. (According to the coreferentiality theory, the occurrence of "it" in (5) presupposes coreference.) *Prima facie*, all talk of coreference is here vacuous, for "a fish" in (5) does not (on the so-called non-referential interpretation of (5)) refer to any particular submarine beast rather than another, and hence apparently cannot be said to refer to the same (or a different) fish as any other term. Yet the sense in which the coreferentiality idea applies here is transparently clear on the possible-world approach: in each possible world compatible with John's wants he catches a fish and eats that fish for supper. The fact that in different possible worlds different specimens of fish undergo this fate does not spoil this coreference in each world, considered alone.

There remains the problem, however, of formulating the precise rules for this kind of coreferentiality in English. Part of the difficulty here is due to the fact that the account just given presupposes, logically speaking, that in such pairs of sentences as

(5a) John was trying to catch a fish. He wanted to eat it for supper.

"it" is within the scope of the operator tacitly introduced by "was trying". This does not seem to be the case in any grammatically natural sense of "scope". Here it is very hard to see the connection between "logical form" and "grammatical form" of the sentences in question.

This difficulty seems to be due to the way in which quantifying expressions operate in ordinary language. What goes on there is *prima facie* quite unlike ordinary quantification theory, where the scopes of the several quantifiers are the main determinants of logical structure. What happens is, rather, that ordinary language uses--for reasons that are likely to be quite deep--for the purposes of quantification, scopeless ("free") terms not completely unlike Hilbert's ε-terms.[3/] [4/] What matters here is not the respective scopes of these terms, for they are typically maximal (comprising as much discourse as belongs to one and the same occasion), but rather the order in which they are thought of as being introduced. There seems to be a fair amount of data concerning in effect the grammatical indicators of this order. However, the study of "natural logic" seems to have been hampered here by the absence of an appropriate logical framework. Linguists and linguistically oriented logicians should here pay much more attention to such unconventional reformulations of quantification theory or Hilbert's ε-theory.

One of the indicators sometimes used in ordinary language for this purpose is simply the order in which the complex terms appear in ordinary language. Since this is affected by the passive transformation, this transformation affects in an important way the meaning of the sentence in question. Chomsky's example (*Aspects* p. 224) "every one in this room knows at least two languages" vs. "two languages are known by everyone in the room" illustrates this point. I do not see any evidence for Chomsky's claim that an ambiguity between these is latent in the former (or in its "deep structure").

Here we are already approaching a group of problems which has recently exercised both philosophical logicians and linguists, viz. the ambiguity between what have been called by Donnellan (1966) the referential and the attributive use of certain singular terms, especially definite descriptions. It is exemplified by the ambiguity of

(6) John wants to marry a girl who is both pretty and rich.

Here it may be that beauty and wealth are among John's desiderata for a wife in general, or it may be that John is keen on marrying some particular girl who happens to have these desirable qualities. The former is the attributive reading of (6), the latter the referential reading. For the historically minded, it may be pointed out that the distinction between the two reading belongs to the older stock of a logician's trade. In the Middle Ages, the referential reading would have been said to yield a statement *de re*, the attributive a statement *de dicto*.

The possible-worlds semantics at once shows what the distinction amounts to under any name. Consider a statement which contains a singular term--say "*b*"--and also some modal notions. These notions imply that we are in effect considering several possible worlds over and above the actual one. Now such a statement can often be understood in two different ways. It may be taken to be about the individuals--typically different ones--which the term "*b*" picks out from the several possible worlds we are considering. This yields the *de dicto* statement. However, it can also be taken to be about that particular individual--considered of course as a citizen of several possible worlds--whom the term "*b*" picks out in the actual one. This results in the *de re* statement. For instance,

(7) John believes that the richest man in town is a Republican

may mean that in each possible world compatible with John's beliefs the description "the richest man in town" picks out a Republican. It may also mean that John has a belief about a particular person, who as a matter of fact is the richest man in town, viz the belief that he is Republican.

Letting bound variables range over (well-defined) individuals (in the logical sense of the word), as Quine and others have persuasively argued that we'd better do, we may symbolize the two statements as follows:

(8) $F(a)$ (*de dicto*)

(9) $(Ex)\ (x=a\ \&\ F(x))$ or alternatively

$(x)\ (x=a \supset F(x)$ (*de re*)

Some philosophers of language, e.g., Quine (1956, 1960) have described the ambiguity as a contrast between two interpretations of the verb in question, an opaque and a transparent one. The former is supposed to yield the attributive and the latter the referential reading. Our analysis of the situation shows that these cannot be considered as two unanalysable senses of the verbs in question. In fact, in (9) the so-called transparent sense is analyzed in terms of the opaque one (plus quantifiers). As to the assumption of the ambiguity of the verb in question, we just do not need that hypothesis. Later it will be seen that speaking of two senses of the verb in question is misleading for another reason, too.

Likewise, the contrast between two apparently irreducible uses of definite descriptions postulated by Donnellan seems to me completely unnecessary, for an analysis can be given of the two uses which does not presuppose any irreducible ambiguities or irreducible contents between different ways of using the expressions in question.

This account of the ambiguity at once suggests several conclusions which do not all agree with what the linguists have said of the subject.

First, the _de dicto_--_de re_ ambiguity (if it may be so called) is unlike many other types of ambiguity in that the two senses coalesce in the presence of simple kinds of further information. What this information is, is shown by our semantics. The difference between a statement about the several references of a term "_b_" in certain possible worlds and a statement about the individual actually referred to by this term "_b_" disappears as soon as "_b_" picks out one and the same reference in all these worlds. Depending what these worlds are, this may amount to a simple factual assumption concerning the people in question. For instance, the two readings of (7) collapse if the phrase "the richest man in town" picks out one and the same man in all of John's doxastic alternatives to the actual world. But this, obviously, means nothing but John's having a belief as to who the richest man in town is. And of course it is obvious that if John has such an opinion, the difference between the two interpretations of (7) indeed does not matter.

This power of simple factual assumptions (which of course usually cannot be made) to dissolve the _de dicto_-_de re_ ambiguity by making the two senses coincide seems to me an interesting phenomenon which distinguishes this type of ambiguity from many others. (No factual assumption can apparently eliminate, say, the ambiguity of "flying planes can be dangerous" without ruling out one of its two senses.) It is beautifully accounted for, it seems to me, by the possible-world semantics.

Secondly, our semantical theory shows that the _de dicto-de re_ ambiguity is present only in a context where we have to consider several possible worlds (including the actual one). Typically, but perhaps not quite exclusively, these are contexts involving (non-redundant) modal notions in our wide sense of the word.

Now it has recently been claimed that, on the contrary, the _de dicto-de re_ contrast can be present in non-modal contexts. Since a couple of interesting methodological points are involved in this question, I shall comment briefly on it. Mrs. Partee claims that such sentences as the following:

(10) John married a girl his parents didn't approve of.

(11) Bill caught a snipe.

(12) The man who murdered Smith is insane.

exhibit the same ambiguity as (6) or (7).

For instance, (12) is said to be ambiguous because "either the speaker is asserting of a particular individual, referred to by the definite noun phrase, that that individual is insane; or the speaker is asserting that whoever it is that murdered Smith is insane--i.e., the definite noun phrase gives a characterization of an individual not necessarily otherwise known, and the sentence asserts that whatever individual is so characterized as insane". However, there is no reason, it seems to me, why the speaker should be asserting one of these things as distinguished from the other. Whoever utters (12) is merely claiming that the person who as a matter of fact murdered Smith is insane, and the question whether the speaker has in mind some particular candidate for that role need not be as much as raised.[5] The fallacy involved here seems to be the following. From the fact that a sentence can be split into a disjunction of several sentences by evoking some further feature of the speech-situation in questions, it does not follow that it is ambiguous. Or. to put the same point in more linguistic terms, from the fact that an expression exhibits on ambiguity when imbedded in a certain kind of context it does not follow that it is ambiguous when considered alone.[6]

To illustrate this claim, let me point out that the same fallacy is exhibited by George Lakoff's recent claim (1970, pp. 12-14) that the sentence

(13) That archaeologist discovered nine tablets..

is ambiguous in that it can "mean" that the archaeologist discovered a group of nine tablets or that the tablets he discovered totalled nine in number. The trouble here is brought out by asking: Why should such possibility of a further description of the feats of one archaeologist make (13) ambiguous? Any sentence could be shown ambiguous by parallel arguments, it seems to me. The point to which Lakoff is trying to get at is presumably that if someone's beliefs concerning one archaeologist are explicitly evoked, a distinction has to be made. Thus Lakoff may perhaps be right in thinking that another example of his, viz.

(14) Sam believed that that archaeologist discovered nine tablets.

is ambiguous between what he calls the group-reading and the quantifier-reading. However, this does not in the least go to show that (13) is ambiguous. Lakoff's claim is merely another instance of the same fallacy as Mrs. Partee's.[7]

The further reason Mrs. Partee gives for the alleged ambiguity of such sentences as (10) - (12) is that when they are imbedded in an opaque context, they exhibit the referential-attributive ambiguity. Hence, the argument seems to go, they cannot on their own be partial to one reading (presumably to the referential one). The mistake involved here is again demonstrated by the possible-worlds semantics. It shows that it is not the case that such non-modal sentences as (10) - (12) for some reason have to be given the referential rather than attributive reading. Rather, the very distinction referential vs. attributive does not apply to non-modal contexts. Hence Mrs. Partee's argument presupposes that her opponents are assuming the referential reading of non-modal sentences, whereas the true moot point is whether the distinction applies to such sentences in the first place.

Another point which the possible-worlds semantics serves to bring out is that the referential-attributive contrast has much less to do than people commonly assume with the relative emphasis on the naming of a particular object in contrast to describing it. Rather, the importance of the descriptive element in the de dicto interpretation is secondary, derived from a deeper feature of the situation. According to the de dicto interpretation, the statement in question deals with the several individuals which a noun or noun phrase picks out in several different possible worlds. Since they are not (manifestations of) the same individual, we often--but not always--have to rely on their descriptive characteristics to pick them out from among the members of the world in question. They are not automatically picked out by the general criteria we have for identity of one and the same individual in different worlds.

Although the descriptive element is therefore often quite important, it is not uniformly so. As soon as it can be assumed for any reason whatsoever that a singular term picks out a definite individual from each of the worlds we are considering, however different these individuals may be, we have an opening for the attributive reading, even though the singular term in question has little descriptive content. It has been claimed (Partee (1970)) that "names are almost always used referentially, since they have virtually no descriptive content". Questions of frequency aside, there nevertheless is no difficulty whatsoever in finding examples of the attributive use of names. For instance, consider the following:

(15) Sherlock Holmes believes that the murder was committed by Mr. Hyde, although he does not know who Mr. Hyde is.

Here a *de dicto* reading is the only natural one. Since Sherlock Holmes is assumed not to know who Mr. Hyde is, his belief can scarcely be said to be about any particular person. (In the different worlds compatible with his knowledge and presumable even with his beliefs, Mr. Hyde will be a different person.)

Notice, moreover, that (15) does not amount to saying that Sherlock Holmes is looking for *a man called* Mr. Hyde, for he is not at all interested, say, in Hyde's namesake in Manchester with a perfect alibi. Hence, we cannot in this way give "Mr. Hyde" in (15) a normal descriptive content.

By the same token, a wide class of sentences in terms of names admit of a *de dicto* reading, assuming that they contain words for knowledge, belief, memory, wishing, hoping, wanting, etc.

Such observations strongly suggest, incidentally, that much of the terminology in this area is misleading. This is the case with the terms "referential" and "attributive" as well as (though to a lesser degree) "*de re*" and "*de dicto*".

Mistaken emphasis on the descriptive element in the attributive (_de_ _dicto_) use of nouns and noun phrases has apparently led to a misclassification of some interesting examples. For instance, we read that the following sentence "seems unambiguously non-referential":

(16) Since I heard that from a doctor, I'm inclined to take it seriously.

Insofar as the _de_ _dicto_-_de_ _re_ distinction is here applicable at all, the presumption seems to me to be that a _de_ _re_ (referential) reading is being presupposed here rather than the _de_ _dicto_ (non-referential) one. For whoever utters (16) is surely likely not to have in mind some definite person from whom he heard whatever he is there said to have heard. In other words, (16) is naturally taken to be equivalent to something like

(17) Since the man from whom I heard that is a doctor,
I am inclined to take it seriously.

which shows that we are dealing with a _de_ _re_ reading here.

A point which I can raise but not answer here concerns a possible moral of the _de_ _dicto_-_de_ _re_ ambiguity for such claims as Lakoff's concerning the near-identity of grammar and "natural logic". This claim is trivial if it only extends to the identity of _some_ grammatical and logical phenomena. Moreover, there are surely features of grammar (in any reasonable sense of the word) which have little logical interest. Hence Lakoff's thesis has a bite only if it is taken to claim that all or at the very least all really interesting features of the logical behavior of ordinary language can be turned into "rules relating surface forms to their corresponding logical forms".

Another restraint that is needed to make Lakoff's claim relevant is the following. The thesis must presuppose some idea what the rules of grammar are independently of the requirement that they match (or can be interpreted as) rules of logic. For if there is no such independent criterion, Lakoff's thesis can be satisfied trivially, simply by taking some suitable formulation (if any) of the relevant aspects of logic and postulating grammatical relations and rules to match these. The real question, it seems to me, is not whether this is possible, but whether such an attempt to satisfy Lakoff's thesis is likely to produce results that have some independent grammatical significance.

My modest proposal here is to use the _de dicto-de re_ ambiguity as a test case for such theses as Lakoff's. If they are correct, this ambiguity must be possible to account for in the usual way in grammatical terms. If my diagnosis of the situation is correct, we have here a widespread and clear-cut phenomenon whose explanation in grammatical terms would be of considerable interest. Because from a logical point of view we can see the unity of the different manifestations of the ambiguity, according to Lakoff's thesis we presumably ought to be able to give to it a unified grammatical treatment.

I have no proof that such a treatment is impossible. As far as I can see--and here I may very well be mistaken--there nevertheless are some definite difficulties confronting any attempt to account for the ambiguity in a satisfactory manner in ordinary grammatical terms. In an old-fashioned terminology, we might say that here linguistic form perhaps does not match logical form.

As I said, I have no strict impossibility proof here, and I do not believe that such a proof is possible until some explicit restraints are imposed on the grammar which is supposed to account for the ambiguity.

However, some indications of the nature of the problem can be given. Part of the aim would have to be to derive all sentences of the form

(18) _a_ knows (believes, remembers, hopes, wishes, intends, etc.) that _p_

where nouns or noun phrases occur in _p_ in more than one way. One way is presumably some more or less straightforward imbedding of _p_ in the "knows that" context. However, it is far from clear what the other derivation might look like. Moreover, it does not suffice to provide just one alternative derivation, for when several nouns or noun phrases occur in _p_, we often face (ceteris paribus) a choice, for each of them, whether to interpret it _de dicto_ or _de re_. (Thus _n_ nouns or noun phrases occurring in _p_ may create 2^n-fold ambiguity.)

Incidentally, this suggests that it is misleading to attribute (as Quine among others had done) the ambiguity in question to the verb which serves to express the propositional attitude in question, unless we are prepared to countenance such strange consequences as, e.g., that the number of readings of the verb in question depends on the number of nouns and noun phrases in the imbedded clause. Hence Quine's analysis of the situation appears very suspect.

A fairly obvious candidate for the role of an intermediate stage of the desired derivation would be something of the form

(19) _a_ knows (believes etc.) of _b_ that --- he ---.

or of one of the similar parallel or more complicated forms. It is in fact true that (19) is prejudiced in favor of the _de re_ interpretation much more firmly than the corresponding construction

(20) _a_ knows (believes, etc.) that --- _b_ ---.

Hence the choice of (19) rather than (20) may very well serve to signal that the speaker is opting for the de re interpretation.

However, it is not clear that (19) cannot itself be ambiguous in the same way as (20). An example of the attributive reading of a sentence of the form (19) is perhaps offered by the following:

(21) It is believed of Jack the Ripper that he killed more than thirty women.

thought of as being uttered in a context where complete ignorance of--and complete doxastic disinterest in--the identity of Jack the Ripper is being presupposed. (Would anyone find (21) at all strange if uttered in such circumstances? I doubt it very much.) If so, the alleged possibility of deriving (20) from (19) scarcely serves to explain why (20) is ambiguous.

The fact, registered above, that the two senses involved in a de dicto-de re ambiguity will coalesce as soon as a simple factual assumption is satisfied also seems to militate against any simple-minded attempt to account for it in terms of two different derivations of the ambiguous sentence. It is hard to see how this latter type of duality can be made to disappear by changing certain facts about the world.

The problem is thus to account in grammatical terms for the two features which distinguish the de dicto-de re ambiguity from typical structural ambiguities. These features are (i) the collapse of the different senses into one wherever certain simple kinds of factual information are present and (ii) the dependency of the number of sense on the number of singular terms (nouns and noun phrases) in the sentence in question or in some part of it.

It is perfectly possible to account for these interesting phenomena in a sufficiently sophisticated logical and/or grammatical theory. For instance, there is no difficulty in explaining (ii) in Montague's formal grammars. However, in such cases the question of independent grammatical interest of the account can perhaps be raised.

Moreover, certain widely accepted grammatical theories do not seem to admit of an adequate account of (i) - (ii). For instance, if ambiguities of this kind are to be explained by reference to pre-transformational (i.e. deep structure) base components and if this base component is to be obtained in the simple way assumed e.g. by Chomsky (see e.g. Aspects, pp. 67-68, 120-123, 128), I cannot see any hope for explaining (ii) by means of alternative ways of obtaining the base component. Furthermore, it is even unclear what an account of (i) would look like in terms of typical contemporary grammatical theories.

What is likely to even be more important here, there does not seem to be any independent grammatical reason for postulating a derivation of (20) from (19). Yet we saw that such reasons are needed to prevent Lakoff's thesis from degenerating into a triviality. I cannot help finding it very unnatural to think of (20) as being derived by so circuitous a route as (19). Of course, this may be merely due to my ignorance of grammatical theory. But even if this should turn out to be the case, the onus of proof is very much on the generative semanticists. If they cannot supply one, or some alternative account of the situation, we have here a counter-example to their claims.

A final word of warning is perhaps needed here concerning the further complications into which the possible-word semantics leads us. Or perhaps --hopefully--we rather ought to speak of the complexities it helps to unravel. I have spoken rather casually of this or that individual's making his or its appearance in the different possible worlds we are considering. In reality, the criteria by means of which we actually do this--that is, cross-identify or tell of members of different possible worlds whether these are the same or different--are not unproblematic, at least not for philosophical purposes. Although luckily our possible-worlds semantics enables us to pose some very interesting questions here, it is not even completely clear what structural properties the "world lines" have that connect the different "manifestations" of "roles" of or "counterparts" to or one and the same individual with each other. One such structural question is of a particular concern to the subject matter of this paper. This is the question whether a "world line" may split when we move from a world to its alternatives. If this question is answered affirmatively, we cannot any longer speak light-heartedly of *the* individual (considered as a member of a number of alternative worlds) which a term (e.g., a noun phrase) picks out from the actual world. For if splitting is admissible, there may be in some of the alternative worlds several "manifestations of" or "counterparts to" to this individual. What that would mean is that the whole *de dicto*-*de re* contrast becomes messier. Or, more accurately speaking, the *de re* reading becomes considerably less sharp.

Can we rule out splitting of world lines (of the kind just mentioned)? This question is of a considerable importance to many philosophers of logic and of language, but unfortunately there is nothing remotely like a consensus concerning the answer. Rather plausible arguments both *pro* and *con* can in fact be found in the literature.

Here I cannot survey these arguments. It may nevertheless work while to recall the fact--which I have pointed out elsewhere[8/]--that a prohibition against splitting is essentially tantamount to the most plausible version of the famous principle of the substitutivity of identity which Quine and others have made the cornerstone of their interpretation of the logic of modal notions. If the prohibition against splitting cannot be upheld, Quine is in serious trouble even on a relatively charitable interpretation of his views on modality and reference.

In contrast, allowing world lines to split would not tell in the least against the possible-world semantics as such. It would merely show that some of the phenomena that can be studied by its means exhibit complications that at first do not meet the eye.

The only constructive suggestion I want to offer here is that what looks like splitting is often an indication of something quite different. It often indicates that more than one overall principle of cross-identification is at work.

Elsewhere[9] I have studied some such contrasts between different methods of cross-identification in some detail. I do not think that I exaggerate if I say that they turn out to have a tremendous philosophical interest. The reason why I mention them here is that recognizing the frequent presence of different principles of cross-identification is highly relevant to the theory of reference as it has been employed by linguists, especially to some of the puzzle examples that have been bandied around in the literature. Suffice it here to point out that the logic of McCawley's well-known example becomes crystal clear from this point of view. I mean of course the sentence

(22) I dreamt that I was Brigitte Bardot and that I kissed me.

Here it is abundantly clear that in the speaker's dream-worlds (worlds compatible with what he dreams) there were two counterparts of him. It is also clear that they are counterparts in a different sense. What precisely the two respective senses are is not specified by the example and may be difficult to spell out in detail. It is fairly clear, nonetheless, that the distinction participant-observer, employed by some analysts, does not give us much mileage here, althouth it perhaps points to the right direction. However, the outlines of the two cross-identification principles used in the example are clear enough. One of the speaker's counterparts is the person whose experiences he has in the dream-world, the other is the one who is like him by some less exciting criteria.

Much work remains to be done concerning different kinds of principles of cross-identification. For one thing, it has not been worked out what consequences the presence of the methods of cross-identification has grammatically. I believe that the contrast is not expressed in English very systematically, although in a somewhat smaller scale it has some clear-cut linguistic counterparts. (See my analysis of the direct-object constructions in the papers mentioned in footnote 3 above.) These counterparts largely remain to be further investigated. It may be the case, as Lakoff has urged, that for this purpose the usual simple-minded method of referential indices, first proposed by Chomsky, is insufficient, though no hard proof to this effect has been given. (Lakoff's analysis seems to me misleading in any case in that he speaks of a person's splitting into several in another possible world. The presence of two different methods of cross-identification is nevertheless a phenomenon which ought to be sharply distinguished from the splitting of individuals under one and the same method.) However, they do not reflect in the least on the possible-worlds semantics, which on the contrary gives us excellent methods of analysing the situation. And since the possible-worlds semantics which I have informally sketched here can easily be turned into an explicit treatment of this part of logic by means of an explicit axiomatization, I cannot agree with Lakoff's claim that "symbolic logic ... is of no help here" (1968, p. 5), though Lakoff may provide a way out for himself be by speaking "symbolic logic of the traditional sort". Traditional or not, a satisfactory logical account here does not fall with the use of referential indices.

Since I have been criticizing many of the specific things logically minded linguists have recently said, let me end by reiterating that I find their direction of interest not only worthwhile but also distinctly promising. The corrections I have tried to offer to their claims are calculated to illustrate this promise rather than to detract from it. I am especially deeply indebted to the authors whose detailed remarks I appear to be criticizing most, viz. to George Lakoff and Barbara Hall Partee.

Notes

1. Probably the best brief account of this approach is still to be found in the original papers by Saul Kripke. Cf. also my Models for Modalities, Kaplan (1969), Kanger (1957), and the writings of Montague.

2. This account is in need of a major qualification, however, for as it stands it implies that we all believe all the logical consequences of what we believe, that having inconsistent beliefs entails believing everything, plus all the awkward parallel conclusions for other propositional attitudes. The problem arising here is discussed by Barbara Hall Partee in her contribution to the present meeting. I have outlined a solution to the problem in other papers, especially in "Knowledge, Belief, and Logical Consequence", Ajatus vol. 32 (1970) and in "Surface Information and Depth Information", Information and Inference, ed. by Jaakko Hintikka and Patrick Suppes, Synthese Library, D. Reidel Publishing Co., Dordrecht, 1970, pp. 263-297.

3. See David Hilbert and Paul Bernays, Grundlagen der Mathematik I-II, Springer - Verlag, Berlin, 1934-39.

4. I recall that Paul Ziff used to make the same--or at least closely related--point in discussion already some twelve years ago.

5. Notice that there is no ambiguity in the truth-conditions of (10 - (12). For instance, (10) is true if and only if John's bride actually was not approved of by his parents, quite independently of the specificity of the speaker's knowledge of who that girl is.
Notice also the interesting difference between what is claimed by Partee about (10) and what in fact happens in (6). Here, it is suggested, it

makes a difference whether the speaker has in mind a particular girl or not. This is an entirely different thing from John's having a specific girl in mind in the state of affairs described by (6). The ambiguity that is claimed to reside in (10) is not the same one that surfaces in (6).

6. Another, supplementary mistake may also be operative here, viz. a tacit assumption that the sentences in question, e.g., (10) - (12) are to be thought of as asserted by the speaker. If so, their logical force will in fact be tantamount to the following:

(10)* I assert that John married a girl his parents didn't approve of.

(11)* I assert that Bill caught a snipe.

(12)* I assert that the man who murdered Smith is insane.

Since "assert" is a modal verb, (10)* - (12)* are indeed ambiguous. However, there is no reason for thinking that the logic of (10) - (12) must be brought out by considering them as asserted sentences. Hence the tacit assumption is likely to be illicit.

7. What has probably misled many people here is the very fact illustrated by Lakoff's claim, viz. the fact that surprisingly often modal notions are tacitly being considered in apparently non-modal contexts. This important fact would deserve some further attention, and it partly excuses the kind of mistake I have been criticizing.

8. In "Existential Presuppositions and Uniqueness Presuppositions" (Models for Modalities pp. 112-147).

9. See "On the Logic of Perception" in Models for Modalities, "Objects of Knowledge and Belief", and "Knowledge by Acquaintance--Individuation by Acquaintance".

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DTHAT

David Kaplan

[Stream of Consciousness Draft: Errors, confusions and disorganizations are not to be taken seriously]

Donnellan says "Using a definite description referentially a speaker may say something true even though the description correctly applies to nothing". His example - taken from Linsky - has someone saying of a spinster,

Her husband is kind to her

after having had Mr. Jones - actually the spinster's brother - mis-introduced as the spinsters husband. And - to fill it out - having noticed Jones' solicitous attention to his sister. The speaker used the non-denoting description "Her husband" to refer to Mr. Jones. And so, what he said was true.

There are a lot of entities associated with the utterance of "Her husband is kind to her" which are commonly said to have been said: tokens, types, sentences, propositions, statements, etc. The something-true-said, Donnellan calls a "statement".

On the other hand, "If... the speaker has just met the lady and, noticing her cheerfulness and radiant good health, made his remark from his conviction that these attributes are always the result of having good husbands, he would be using the definite description attributively."

After pointing out that "In general, whether or not a definite description is used referentially or attributively is a function of the speakers intentions in a particular case", he mentions that according to Russell's theory of descriptions, the use of the 0 might be thought of as involving reference "in a very weak sense" to whatever is the one and only one 0, if there is any such. Donnellan then concludes, "Now this is something we might well say about the attributive use of definite descriptions... But this lack of particularity is absent from the referential use of definite descritpions precisely because the description is here merely a device for getting one's audience to pick out or think of the thing to be spoken about, a device which may serve its function even if the description is incorrect. More importantly perhaps, in the to be picked out by the audience, and its being the right thing

referential use as opposed to the attributive, there is a right thing is not simply a function of its fitting the description ."

Donnellan develops his theory by adducing a series of quite plausible examples to help him answer certain theoretical questions, e.g. are there sentences in which the contained definite description can only be used referentially (or only attributively)?, can reference fail when a definite description is used referentially?, etc.

In my own reading and re-reading of Donnellan's article I always find it both fascinating and maddening. Fascinating, because the fundamental distinction so clearly reflects an accurate insight into language use, and maddening, because: first, the examples seem to me to alternate between at least two clearly discriminable concepts of referential use, second, the notion of having someone in mind is not analyzed but used, and third, the connections with the developed body of knowledge concerning intensional logics - their syntax and semantics - are not explicitly made, so we can not immediately see what Donnellan and intensional logic have to offer each other, if anything.

As one of the body devlopers, I find this last snub especially inexcusable. This is not a divergent perception for those of my ilk. Hintikka remarks (plaintively?) "The only thing I miss in Donnellan's excellent paper is a clear realization that the distinction he is talking about is only operative in contexts governed by propositional attitudes or other modal terms".

Hintikka's remark at first seems surprising, since none of Donnellan's examples seem to have this form. But the remark falls into place when we recognize that Donnellan is concerned essentially with a given speaker who is asserting something, asking something, or commanding something. And thus if we pull back and focus our attention on the sentence describing the speech act:

John asserted that Mary's husband is kind to her.

the intensional operator appears.

Probably Hintikka wanted to argue that the sentence,

Her husband is kind to her,

is not itself ambiguous in the way that say,

Every boy kissed a girl.

is. The fact that an ambiguous sentence is produced by embedding Ø in some sentential context (for example, an intensional or temporal operator) should not be construed to indicate an ambiguity in Ø. For were it so, (almost?) all sentences would be ambiguous.

Donnellan's distinction is a contribution to the re-development of an old, and common-sensical theory about language that - at least in the philosophical literature - has rather been in a decline during the ascendency of semantics over epistemology of the 30's, 40's and 50's. The common sense theory is one that Russell wrestled with in *Principles of Mathematics* (1903) but seemed to reject in "On Denoting" (1905). This theory asserts roughtly that the correct analysis of a typical speech act, for example,

John is tall,

distinguishes *who* is being talked about i.e. the individual under consideration, - here, John - from *how* he is being characterized - here, as tall.

Russell's analysis of the proposition expressed by

John is tall,

provides it with two components: the property expressed by the predicate "is tall", and the individual John. That's right, John himself, right there, trapped in a proposition.

During the Golden Age of Pure Semantics we were developing a nice homogenious theory with language, meanings, and entities of the world each properly segregated and related one to another in rather smooth and comfortable ways. This development probably came to its peak in *Meaning and Necessity.* Each 'designator' has both an intension and an extension. Sentences have truth values as extensions and propositions as intension, predicates have classes as extensions and properties as intension, terms have individuals as extension and 'individual concepts' as intension, and so on. The intension of a compound is a function of the intensions of the parts and similarly the extension. There is great beauty and power in this theory.

But there remained some nagging doubts: Proper names, demonstratives, and quantification into intensional contexts.

Proper names may be a practical convenience in our mundane transactions, but they are a theoretician's nightmare. They are like bicycles. Everyone easily learns to ride, but no one can correctly explain how they do it. Completely new theories have been proposed within the last few years, in spite of the fact that the subject has received intense attention throughout this century, and in some portions of Tibet people have had proper names for even longer than that.

The main difficulty has to do, I believe, with the special intimate relationship between a proper name and it's bearer. Russell said that in contrast with a common noun, like "Unicorn", a proper name means what it names. And if it names nothing, it means nothing. In the case of "unicorn" we have a meaning, perhaps better a "descriptive meaning", which we make use of in looking for such things. But in the case of the name "Moravcsik" there is just Moravcsik. There is no basis on which to ask whether Moravcsik exists. Such a question is - for Russell - meaningless.

But people persist in asking this question. Maybe not this very question, but analogous ones like

Does Santa Claus exist?

Then there were other apparent difficulties in Russell's theory. The Astrononical discovery that Hesperus was identical with Phosphous became a triviality. It expressed the same proposition as Hesperus is identical with Hesperus. Furthermore, although the bearer of given proper name is the be-all and end-all of the name's semantic relata, almost every proper name has dozens of bearers.

And then there are the unforgiveable distortions of the minimal descriptive content of proper names. We all know of butchers named "Baker" and dogs named "Sir Walter". The ultimate in such perversity occurs in titles of the top administrative officers at UCLA. We have four vice-chancellor's at UCLA, one of whose title is "The Vice-Chancellor"

All in all proper names are a mess and if it weren't for the problem of how to get the kids to come in for dinner, I'd be inclined to just junk them.

At any rate the attempt during the Golden Age was to whip proper names into line. In fact into the line of common nouns. People do ask

Does Santa Claus exist?

So that must mean something like

Does a unicorn exist?

They do ask

Is Hesperus identical to Phosphorous?

So that must mean something like

Are bachelors identical with college graduates?

Thus was waged a war of attrition against proper names. Many were unmasked as disguised descriptions e.g. "Aristotle" means "The student of Plato and teacher of Alexander who..." - not an unreasonable proposal. -

However some of these exposés did seem a bit oppressive. e.g. Russell's suggestion that

Scott is Sir Walter.

really means

the person named 'Scott' is the person named 'Sir Walter'.

followed by his nonchalant remark: "This is a way in which names are frequently used in practice, and there will, as a rule, be nothing in the phraseology to show whether they are being used in this way or as names". But at least they isolated the few real trouble makers - who turned out not to be our good old proper names at all but a handful of determined outside demonstratives - 'This', 'that', etc.

In summary, the technique was first to expose a proper name as a disguised discription (sometimes on tenuous and unreliable evidence) and then ruthlessly to eliminate it.

We thus reduce the exciting uncertainties of,

Socrates is a man.

to the banality of,

All men are mortal

The demonstratives were still there but they were so gross they could be ignored.

Lately, under the pressure of the new interest in singular propositions generated by intensional logic, the verities of the Golden Age are breaking down. Once logicians became interested in formalizing a logic of necessity, belief, knowledge, assertion, etc., traditional syntactical ways quickly led to formulas like

John asserted that x is a spy

with free 'x', and then with 'x' bound to an anterior operator. Under what circumstances does a given individual, taken as value of 'x', satisfy this formula? Answer: if the appropriate singular proposition was the content of John's assertive utterance.

It seems that in at least certain speech acts, what I am trying to express can't quite be put into words. It is that proposition of Russell's with John trapped in it.

The property of being tall is exactly expressed by 'is tall', and the concept of the unique spy who is shorter than all other spies is exactly expressed by 'the shortest spy'; but no expression exactly expresses John. An expression may express a concept or property which, in reality, only John satisfies. There are many such distinct concepts; none of which is John himself.

I would like to distinguish between the kind of propositions which were considered by Aristotle (all S is P, some S is not P, etc.) and the kind of proposition considered by the early Russell. I call the former general propositions and the latter singular propositions. Suppose, just for definiteness, that we fix attention on sentences of simple subject-predicate form. The following are examples:

(i) A spy is suspicious

(ii) Every spy is suspicious.

(iii) The spy is suspicious.

(iv) John is suspicious.

Now let us think of the proposition associated with each sentence as having two components. Corresponding to the predicate we have the property of being suspicious; and corresponding to the subject we have either what Russell called a denoting concept or an individual. Let us take the proposition to be the ordered couple of these two components.

Again, to fix ideas, let us provide a possible-world style of interpretations for these notions. We think of each total or complete possible state of affairs as a possible world. The possible worlds are each continuants through time and may in fact overlap at for certain times. For example, a possible world may agree with the actual world up to the time at which some individual made a particular decision; the possible world may then represent an outcome of a decision other than the one actually taken. (In science fiction, such cases are called alternate time lines.)

Within this framework we can represent a number of the semantic notions in question. We might represent the property of being suspicious by that function P which assigns to each possible world w and each time t, the set of all those individuals of w which, in w, are suspicious at t. We might represent the denoting concepts expressed by the denoting phrases 'A spy', 'Every spy', and 'The spy' as, say, the ordered couples: $\langle$'A',S$\rangle$, $\langle$'Every',S$\rangle$, $\langle$'The', S$\rangle$ where S is the property (represented as above) of being a spy.[1] The fact that the logical words 'A', 'Every', and 'The' are just carried along reflects our treatment of them as syncategorematic; i.e. as having no independent meaning but as indicators of how to combine the meaning bearing parts (here: 'spy' and the predicate) in determining the meaning of the whole. For (i), (ii), (iii) the corresponding propositions are now represented by:

(v) $\langle\langle$'A'S$\rangle$ P$\rangle$

(vi) $\langle\langle$'Every' S$\rangle$ P$\rangle$

(vii) $\langle\langle$'The' S$\rangle$ P$\rangle$

It should be clear that each of (v) - (vii) will determine a function which assigns to each possible world w and time t a truth value. And in fact the truth value so assigned to any w and t will be exactly the truth value of the sentence in w at t. For example: (vi) determines that function which assigns Truth to a given w and t if and only if every member of S(w,t) is a member of P(w,t). Notice that the function so determined by (vi) also correctly assigns to each w and t the truth value of (ii) in w at t. [For the purpose of (vii), let us take * to be a 'truth value' which is assigned to w and t when S(w,t) contains other than a single member.]

The proposition corresponding to (iv) would be:

(viii) ⟨John, P⟩ ,

not ⟨'John', P⟩ mind you, but ⟨John,P⟩. And (viii) will determine that function F which assigns Truth to w and t if and only if John is a member of P(w,t). If John is an individual of w at the time t (i.e. John exists in w and is alive at t) but is not a member of P(w,t), then F(w,t) is Falsehood; and if John is not an individual of w at the time t, then F(w,t) is *.

This brief excursion into possible world semantics is only to fix ideas in a simple way within that framework (I will later make further use of the framework) and is not put forward as an ideal (in any sense; generalizability, elegance, etc.) representation of the semantic notions of property, proposition, denoting concept, etc. My main motivation is to present a representation which will clearly distinguish singular and general propositions.

It would, of course, have been possible to supply a representation of the proposition expressed by (iv) which is, in a sense, formally equivalent to (viii) and which blurs the distinction I wish to emphasize. I do it now lest anyone think that the possibility is a relevant refutation of my later remarks. Let us clearly depart from Russell by associating a denoting concept also with the denoting phrase 'John'. We might use (ix) ⟨'Proper Name' J⟩, where J is what we might call *John's essence*, the property of *being John*, namely that function which assigns to each possible world w and time t the set {John} if John is an individual of w and is alive in w at t and the empty set otherwise, ~~[illegible]~~. The analogue to (viii) is now (x) ⟨⟨'Proper Name' J⟩ P⟩.

It will be noted that we have now treated the proper name 'John' rather like the definite description 'The John' in which the proper name plays the role of a common noun. Accordingly the function from possible worlds and times to truth values which is determined by (x) is identical with that determined by (xi) $\langle\langle$ 'The' J$\rangle$ P$\rangle$.

There are certainly other representations of these propositions which ally various subgroups. In fact once any formal structure is established, the production of isomorphic structures satisfying specified 'internal' conditions is largely a matter of logical ingenuity of the 'pure' kind.[2]

To return to the point, I have represented propositious in a way which emphasizes the singular — general distinction, because I want to revive a view of language alternate to that of the Golden Age. The view of the Golden Age is, I believe, undoubtedly correct for a large portion of language behavior, in particular, communication by means of general propositious. But the alternate view accounts for a portion of language behavior not accommodated by the view of the Golden Age.

The alternate view is: that some or all of the devoting phrases used in an utterance should not be considered part of the content of what is said but should rather be thought of as contextual factors which help us to interpret the actual physical utterance as having a certain content. The most typical of such contextual factors is the fact that the speaker's utterance is to be taken as an utterance of some specific language, say, English. When I utter "Yes", which means Yes in English and No in Knoh, you must know I am speaking Knoh to know I have said No. It is no *part* of what I have said that I am speaking Knoh, though Knoh being a compleat tongue I could add that by uttering "I am speaking English". Such an utterance is of doubtful utility in itself; but fortunately, there are other means by which this fact can be ascertained by my auditor, e.g. by my general physical appearance, or, if I am not a native Knoh, by my pointing to Knoh an a celestial globe. A homelier example has a haberdasher utter to a banker "I am out of checks". Whether the utterance takes place in the store or at the bank will help the banker to determine what the haberdasher has said. In either case it is no *part* of what was said that the haberdasher used "checks" to mean bank checks rather than suits with a pattern of checks. Of course the haberdasher could go on, if he desired, to so comment on his past performance; but that would be to say something else. Still closer to home is my wife's utterance: "Its up to you to punish Jordan for what happened today." It is by means of various subtle contextual clues that I understand her to be charging me to administer discipline to our son and not to be calling on me to act where the United Nations have failed. Again, should I exhibit momentary confusion she might, by a comment, a gesture, or simply some more discourse on the relevant naughtiness, assist me in properly decoding her first utterance so that I could understand what she was, in fact, saying. There are other ways--more controversial than the intentional resolution of the reference of a proper name among the many persons so dubbed--in which contextual factors determine the content of an utterance containing a proper name; but I am reserving all but the most blatantly obvious remarks for later.

Now let us narrow our attention to utterances containing *singular denoting phrases* (i.e. denoting phrases which purport to stand for a unique individual, such as " the spy", "John", "$\sqrt{2}$ ", etc.).[2a]

How can contextual factor determine that part of the content of an utterance which corresponds to a singular denoting phrase? Two way have already been mentioned: by determining what language is being spoken and by determing which of the many persons so dubbed a proper name stands for. But the most striking way in which such contextual factors enter is in connection with *demonstratives*: "This", "This spy", "That book", etc. In at least some typical uses of these phrases, it is required that the utterance be accompanied by a *demonstration* -- paradigmatically, a pointing -- which indicates the object for which the phrase stands.[3] I will speak of a *demonstrative use* of a singular denoting phrase when the speaker intends that the object for which the phrase stands be designated by an associated demonstration.[4]

Now we can add another example of a subject-predicate sentence to those of (i) -- (iv).

(xii) He [the speaker points at John] is suspicious. I am adopting the convention of enclosing a description of the relevant demonstration in square brackets immediately following each denoting phrase which is used demonstratively.[5]

What shall we take as the proposition corresponding to (xii) (which I also call the *content* of the *utterance* (xii))? In line with our program of studying contextual factors which are not *part* of what is said but whose role is rather to help us interpret the utterance as having a certain content, we shall take as the component of the proposition which corresponds to the demonstrative, the individual demonstrated. Thus the varying forms which such a demonstration can take are not reflected in the content of the utterance (i.e. the proposition). The demonstration 'gives us' the element of the proposition corresponding to the demonstrative. But how the demonstration gives that individual to us is here treated as irrelevant to the content of the utterance; just as the different ways by which I might have come tp understand which Jordan was relevant to my wife's utterance, or the different ways by which one might come to understand that a speaker is speaking Knoh rather than English, do not alter the content of those utterances. Thus, for example, the utterances (in English)

(xiii) He [the speaker points at John, as John stands on the demonstration platform rude, cleanshaven, and bathed in light] is suspicious.

(xiv) He [the speaker points at John, as John lurks in the shadows wearing a trenchcoat, bearded, with his hat pulled down over his face] is suspicious.

are taken, along with other refinements of (xii), as expressing the same proposition, namely:

(xv) $\langle$John, P$\rangle$.

It should immediately be apparent that we are in store for some delightful anomalies. Erroneous beliefs may lead a speaker to put on a demonstration which does not demonstrate what he thinks it does, with the result that he will be under a misapprehension as to what he has said. Utterances of identity sentences containing one or more demonstratives may express necessary propositions, though neither the speaker nor his auditors are aware of that. In fact, we get extreme cases in which linguistic competance is simply insufficient to completely determine the content of what is said. Of course this was already established by the case of the Knoh--English translation problem, but the situation is more dramatic using the demonstratives.

The present treatment is not inevitable. An alternative is to incorporate the demonstration in the proposition. We would argue as follows: Frege's *sense and denotation* distinction can be extended to all kinds of indicative devices. In each case we have the object indicated (the 'denotation') and the manner of indication (the 'sense'). It is interesting to note that (at least in Feigl's translation) Frege wrote of "the sense (connotation, meaning) of the sign in which is contained the *manner and context* of presentation of the denotation of the sign ".[6] I think it reasonable to interpret Frege as saying that the sense of a sign is what is grasped by the linguistically competent auditor, and it seems natural to generalize and say that it is the 'sense' of the demonstration that is grasped by the competant auditor of utterances containing demonstratives. Thus we see how the drawn-out English utterance.

(xvi) That [the speaker points at Phosporus in early morning] is the
same planet as that [the speaker points at Hesperus in early evening] .

could be both informative and true.

Let us call the preceding a *Fregean treatment of demonstratives*. It is worth developing (which mean primarily working on the ontology (metaphysics?) of demonstrations and the semantics of demonstration descriptions) but, I believe, will ultimately be unsatisfactory. For now I'll just outline some of the reasons. The demonstrative use of demonstratives plays an important role in language learning, in general in the learning and use of proper names, in our misty use of *de re* modalities, in our better grounded use of what Quine calls the *relational* senses of epistemic verbes (i.e. the senses of these intensional verbs that permit quantification in). And, in general, I believe that we can sharpen our epistemological insights in a number of areas by taken account of what I call the demonstrative use of expression. Such uses are far more widespread than one imagined.

I earlier called the Fregeam treatment of demonstratives "unsatisfactory". I would be more cautious in saying that it was wrong (though I think an empirical argument from linguistic behavior could be developed to show that it is wrong. I take Donnellan's study of the phenomenology of what he calls referential use to be an excellant start in that direction.) What I am confident of is that if we force all phenomena that suggest a special demonstrative use of language, along with what I regard as a corresponding feature: a special singular form of proposition, into the Fregean mold of linguistic elements with a sense and a denotation, the sense being the element which appears in the proposition (thus leaving us with only general proposition), then important insights will be lost. I don't deny that on a phenomenon by phenomenon basis we can (in some sense) keep stretching Frege's brilliant insights to cover. With a little ingenuity I think we can do that. But we shouldn't.

Now let me offer a slightly different and somewhat a priori justification for studying the phenomena of demonstrative uses of expressions and singular propositions. I leave aside the question of whether we have correctly analyzed any actual linguistic behavior, whether concerned with the so-called demonstrative phrases or otherwise. ¶ Having explained so clearly and precisely what such a use of language would amount to, in terms of a possible world semantics, I can simply resolve to so use the word "that" in the future. At a minimum I could introduce the new word "dthat" for the demonstrative use of "that". Couldn't I? I can, and I will. In fact, I do.

I like this intentional (i.e. stipulative) way of looking at the use of "dthat" because I believe that in many cases where there are competing Fregean and demonstrative analyses of some utterances or class of utterances the matter can be resolved simply by the intentions of the speaker (appropriately conveyed to the auditor?). Thus in the case of proper names (to which I will return below) I might simply resolve to use them demonstratively (i.e. as demonstrating the individual whom they are a name *of*, in the nomenclature of an earlier paper)[7] on certain occasions and in a Fregean way[7a] on other occasions. Of course one who did not have a clear understanding of the alternatives might have difficulty in characterizing his own use, but once we have explored each choice there is nothing to prevent us from choosing either, 'unnatural' though the choice may be.

It should probably be noted that despite the accessibility of the semantics of "dthat" our *grasp* of the singular propositions so expressed is, in John Perry's apt phrase, a bit of knowledge by description as compared with our rather more direct acquaintance with the general propositions expressed by non-demonstrative utterances.

Armed with "dthat" we can now explore and possibly even extend the frontiers of demonstrations.

When we considered the Fregean analysis of demonstrations, we attempted to establish parallels between demonstrations and descriptions.[8] Insofar as this aspect of the Fregean program is successful, it suggests the possibility of a demonstrative analysis of descriptions. If pointing can be taken as a form of describing, then why not take describing as a form of pointing? Note that our demonstrative analysis of demonstrations need not, indeed should not, deny or even ignore the fact that demonstrations have both a sense and a demonstratum. It is just that according to the demonstrative analysis the sense of the demonstrations does not appear in the proposition. Instead the sense is used only to fix the demonstratum which itself appears directly in the proposition. I propose now to do the same for descriptions. Instead of taking the sense of the description as subject of the proposition, we use the sense only to fix the denotation which we then take directly as subject component of the proposition. I now take the utterance of the description as a demonstration and describe it with the usual quotation devices, thus:

(xvii) Dthat ["the spy"] is suspicious.

For fixity of ideas, let us suppose, what is surely false, that in fact, actuality, and reality, there is one and only one spy, and John is he. We might express this so: (xviii) "the spy" denotes John.[9] In the light of (xviii), (xvii) expresses (xix) ⟨John, P⟩ (also known as (viii) and (xv)).

Recollecting and collecting we have:

(iii) The spy is suspicious.

(iv) John is suspicious.

(vii) ⟨⟨'The' S⟩ P⟩

(xii) He [the speaker points at John] is suspicious,

or, as we might now write (xii), (xx) Dhe [the speaker points at John] is suspicious.[9a]

Earlier we said that an utterance of (iii) expresses (vii), and only an utterance of (xii) (i.e.(xx)) or possibly (iv) expresses (xix). I have already suggested that an utterance of (iv) may sometimes be taken in a Fregean way to express something like (vii), and now I want to point out that for want of "dthat" some speakers may be driven to utter (iii) when they intend what is expressed by (xvii).

If an utterance of (iii) may indeed sometimes express (xix), then Donnellan was essentially correct in describing his referential and attributive uses of definite descriptions as a "duality of function". And it might even be correct to describe this duality as an ambiguity in the sentence type (iii). I should note right here that my demonstrative use is not quite Donnellan's referential use — a deviation that I will expatiate on below — but it is close enough for present purposes.

The ambiguity in question here is of a rather special kind. For under no circumstances could the choice of disambiguation for an utterance of (iii) affect the truth value. Still there are two distinct propositions involved, and even two distinct functions from possible worlds and times to truth values, determined by the two propositions.

Before continuing with the ambiguity in (iii), it would be well to interject some remarks on sentence types and sentence tokens (of which utterances are one kind) especially as they relate to demonstratives.

Sentences types vary considerably in the degree to which they contain implicit and explicit references to features of the context of utterance. The references I have in mind here are those which affect the truth value of the sentence type on a particular occasion of utterance. At one extreme stand what Quine (in *Word and Object*) called *eternal sentence* those in which the feature linguists call *tense* does not really reflect a perspective from some point in time, which contain no *indexicals* such as "now", "here", "I", etc., and whose components names and definite descriptions are not understood to require contextual determination as did the "Jordan" of our earlier example. Quine describes such sentences as "those whose truth value stays fixed through time and from speaker to speaker."[10] But I prefer my own vaguer formulation: *those sentence which do not express a perspective from within space-time*. Quine and I would both count "In 1970 American women exceed American men in wealth" as eternal; he would (resumably) also count "The UCLA football team always has, does, and will continue to outclass the Stanford football team" as eternal, I would not.

Truth values are awarded directly to eternal sentences without any relativization to time, place, etc.[11] But for the fugitive sentence no stable truth value can awarded. Let us consider first tensed sentences, e.g.

(xxi) American men will come to exceed American women in intelligence.

Without disputing the facts, if (xxi) were true at one time, it would fail to be true at some later time. (Since one doesn't come to exceed what one already exceeds.)

Now let's dredge up the possible worlds. We associate with (xii) a functions which assigns to each possible world and time a truth value. Such a function seems to represent, for reasons which have been much discussed, at least part of the meaning of (xxi) or part of what we grasp when we understand (xxi).[12] There is another kind of 'content' associated with a fugitive sentence like (xxi), namely the content of a particular utterance of (xxi). In a sense, any particular utterance (token) of a fugitive sentence (type) is an eternalization of the fugitive sentence. The relativization to time is fixed by the time of utterance. We can associate with each utterance of a fugitive sentence the same kind of function from possible worlds to truth values that we associate directly with enternal sentences.

Before becoming completely lost a vague nomenclature, let me make some stipulations. I will call the function which assigns to a time and a possible world the truth value of a given fugitive sentence (type) at that time in that world, the meaning of the given sentence. The meaning of a sentence is what a person who is linguistically competent grasps, it is common to all utterances of the sentence, and it is one of the components which goes into determing the content of any particular utterance of the sentence. The content of an utterance is that function which assigns to each possible world the truth value which the utterance would take if it were evaluated with respect to that world. There is some unfortunate slack in the preceding characterizations, which I will try to reduce.[13]

Let ϕ be a fugitive sentence like (xxi), let $\overline{\phi}$ be the meaning of ϕ, let W be the set of possible worlds, let T be the set of times (I assume that all possible worlds have the same temporal structure and, in fact, the very same times, i.e. a given time in one world has a unique counterpart in all others), let U be the set of possible utterances, for $u \in U$ let $\mathcal{S}(u)$ be the sentence uttered in u, let $\mathcal{T}(u)$ be the time of u (when only $\mathcal{S}(u)$ and $\mathcal{T}(u)$ are relevant, we might identify u with $\langle \mathcal{S}(u)\mathcal{T}(u) \rangle$ and let $\overline{u}$ be the content of u. The relation between the meaning of a sentence (whose only fugitive aspect is its temporality) and the content of one of its possible utterances can now be concisely expressed as follows.

(xxii) $\bigwedge u \in \mathcal{U} \bigwedge w \in \mathcal{W} \left(\overline{u}\ (w) = \overline{\mathcal{S}(u)}\ \ (\mathcal{T}(u)\ w) \right).$

or, identifying u with $\langle \mathcal{S}(u)\ \mathcal{T}(u) \rangle$

(xxiii) $\bigwedge w \in \mathcal{W} \bigwedge t \in \mathcal{T} \left(\overline{\langle \phi\ t \rangle}\ (w) = \overline{\Phi}\ (t\ w) \right).$

To put it another way, an utterance of ϕ fixes a time, and the content of the utterance takes account of the truth value of ϕ in all possible worlds but only at that time.

From (xxii) and (xxiii) it would appear that the notions of meaning and content are interdefinable. Therefore, since we already have begun developing the theory of meaning for fugitive sentences (see especially the work of Montague) why devote any special attention to the theory of content? Is it not simply a subtheory of a definitional extension of the theory of meaning? I think not. But the reasons go beyond simple examples like (xxi) and take us, hopefully, back to the main track of this paper. It is worth looking more deeply into the structure of utterances than a simple definition of that notion within the theory of [illegible]aning would suggest. (I stress simple because I have not yet really investigated sophisticated definitions.)

First we have problems about the counterfactual status of possible utterances. Are utterances in worlds, are they assumed to occur in worlds in which their content is being evaluated, or are they extraworldly, with their content evaluated independent of their occurrence? Consider the infamous "I am here now", or perhaps more simply,

(xxiv) An utterance is occurring.

Is the meaning of (xxiv) to assign to a time and world, the truth value which an utterance of (xxiv) would take were it to occur in that would at that time? Or does it assign simply the truth value of (xxiv) in that world at that time? Presumably the latter.

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But this is to assume that utterances come complete, with the value of all of their contextually determined features filled in (otherwise the utterance alone - without being set in a world - would not have a content). I do not want to make this assumption since I am particularly interested in the *way* in which a demonstration, for example, picks out its demonstratum.

And now we are back to the ambiguity in (iii). I would like to count my *verbal* demonstration, as in (xvii), as part of the sentence type. Then it seems that an utterance of such a sentence either must include a world, or else, what is more plausible must be in a world. I guess what I want to say, what I should have said, is that an utterance has to occur *somewhere*, in some world, and the world in which it occurs is a crucial factor in determining what the content is. This really says something about how (I think) I want to treat (possible) demonstrations. I want the same (possible) demonstrations (e.g. ["the spy"]) to determine different demonstrata in different worlds (or possibly even at different times in the same world). Now I see why I was so taken with the Fregean treatment of demonstrations. We should be able to represent demonstrations as something like functions from worlds, times, etc. to demonstrata. Thus, just like the meaning of a definite description. The difference lies in how the content of a particular utterance is computed.

I realize that the foregoing is mildly inconsistent, but let us push on. Let u be an utterance of (xvii) in w at t, and let u' be an utterance of (iii) in w at t. Let's not worry, for now, about the possibility of a clash of utterances. If we look at the content of u and the content of u' we will see that they differ - though they will always agree in w. The content of u is like what I earlier called a singular proposition (except that I should have fixed the time). Whereas the content of u' is like what I earlier called a general proposition. For the content of u to assign truth to a given world w', the individual who must be suspicious in w' at t is not the denotation of "the spy" in *w'* at t, but rather the denotation of "the spy" in *w* at t. The relevant individual is determined in the world in which the utterance takes place, and then that same individual is checked for suspicion in all other worlds. Whereas for the content of u', we determine a (possibly) new relevant individual in each world.[14]

What is especially interesting is that these two contents must agree in the world w, the world in which the utterance took place.

Now note that the verbal form of (iii) might have been adopted by one who lacked "dthat" to express what is expressed by (xvii). We seem to have here a kind of *de dicto* - *de re* ambiguity in the verbal form of (iii) and without benefit of any intensional operator. No question of an utterer's intentions have been brought into play. There is no question of an analysis in terms of scope, since there is no operator. The two sentence types (iii) and (xvii) are such that when uttered in the same context they have different contents but always the same truth value where uttered. Donnellan vindicated! (Contrary to my own earlier expectations.)

I am beginning to suspect that I bungled things even worse than I thought in talking about meanings, contents, etc. The meaning of a sentence type should probably be a function from utterances to *contents* rather than from something like utterances to truth values. If this correction were made then we could properly say that (iii) and (xvii) differ in meaning.

It would also give a more satisfactory analysis of a sentence type like,

(xxv) Dthat ["the morning star"] is identical with dthat ["the evening star"]

Although it expresses a true content on some occasions of use and a false content on others, it is not simply contingent. Since on all occasions its content is either necessary or impossible. (I am assuming that distinct individuals don't merge.) Even one who grasped the meaning of (xxv) would not of course know its truth value simply on witnessing an utterance. Thus we answer the question of how an utterance of an identity sentence can be informative though *necessary*.

Another example on the question of necessity. Suppose I now utter:

(xxvi) I am more than 36 years old. What I have said is true. Is it necessary?

This may be arguable. (*Could* I be younger than I am at this very same time?) But the fact that the sentence, if uttered at an earlier time or by another person, could express something false is certainly irrelevant. The point is: to simply look at the spectrum of truth values of different utterances of (xxv) and (xxvi) and not at the spectrum of contents of different utterances of (xxv) and (xxvi) is to miss something interesting and important.

I earlier said that my demonstrative use is not quite Donnellan's referential use, and I want now to return to that point. When a speaker uses an expression demonstratively he usually has in mind - so to speak - an intended demonstratum, and the demonstration is thus teleological. Donnellan and I disagree on how to bring the intended demonstratum into the picture. To put it crudely, Donnellan believes that for most purposes we should take the demonstratum to be the intended demonstratum. I believe that these are different notions that may well involve different objects.

From my point of view the situation is interesting precisely because we have a case here in which a person can fail to say what he intended to say, and the failure is not a linguistic error (such as using the wrong word) but a factual one. It seems to me that such a situation can arise only in the demonstrative mode.

Suppose that without turning and looking I point to the place on my wall which has long been occupied by a picture of Rudolf Carnap and I say,

(xxvii) Dthat [I point as above] is a picture of one of the greatest philosophers of the Twentieth Century.

But unbeknownst to me, someone has replaced my picture of Carnap with one of Spiro Agnew. I think it would simply be wrong to argue an 'ambiguity' in the demonstration, so great that it can be bent to my intended demonstratum. I have said of a picture of Spiro Agnew that it pictures one of the greatest philosophers of the Twentieth Century. And my speech and demonstration suggest no other natural interpretation to the linguistically competent public observor.

Still, it would be perhaps equally wrong not to pursue the notion of the intended demonstratum. Let me give three reasons for that pursuit.

(1) The notion is epistemologically interesting in itself.

(2) It may well happen-as Donnellan has pointed out - that we succeed in communicating what we intended to say in spite of our failure to say it. (e.g. The mischevious fellow who switched pictures on me would understand full well what I was intending to say.)

(3) There are situations where the demonstration is sufficiently ill-structured in itself so that we would regularly take account of the intended demonstratum as, within limits, a legitimate disambiguating or vagueness removing device.

I have two kinds of examples for this 3rd point. First, there are the cases of vague demonstrations by a casual waye of the hand. I suppose that ordinarily we would allow that a demonstration had been successful if the intended object were roughly where the speaker pointed. That is, we would not bring out surveying equipment to help determine the content of the speakers assertion; much more relevant is what he intended to point at. Second, whenever I point at something, from the surveyor's point of view I point at many things. When I point at my son (and say "I love dthat"), I may also be pointing at a book he is holding, his jacket, a button on his jacket, his skin, his heart, and his dog standing behind him - from the surveyor's point of view. My point is that if I intended to point at my son and it is true that I love him, then what I said is true. And the fact that I do not love his jacket does not make it equally false. There are, of course, limits to what can be accomplished by intentions (even the best of them). No matter how hard I intend Carnap's picture, in the earlier described case, I do not think it reasonable to call the content of my utterance true.

Another example where I would simply distinguish the content asserted and the content intended is in the use of "I".[15] A person might utter,

(xxviii) I am a general, intending - that is 'having in mind' - De Gaulle, and being under the delusion that he himself was De Gaulle. But the linguistic constraints on the possible demonstrata of "I" will not allow anyone other than De Gaulle to so demonstrate De Gaulle, no matter how hard they try.

All this familiarity with demonstratives has led me to believe that I was mistaken in "Quantifying In" in thinking that the most fundamental cases of what I might now describe as a person having a propositional attitude (believing, asserting, etc.) toward a singular proposition required that the person be *en rapport* with the subject of the proposition. It is now clear that I can assert *of* the first child to be born in the 21st Century that *he* will be bald, simply by assertively uttering,

(xxix) Dthat ["the first child to be born in the 21st Century"] will be bald.

I do not now see exactly how the requirement of being *en rapport* with the subject of a singular proposition fits in. Are there two kinds of singular propositions? Or are there just two different ways to know them?

EXCITING FUTURE EPISODES:

1. Making sense out of the foregoing.
2. Showing how nicely (iii) and (xvii) illustrate an early point about the possibility of incorporating contextual factors (here, a demonstration) as part of the content of the utterance. Another example compares uses of "the person I am pointing at" as demonstration and as subject.
3. Justifying calling (xvii) a de re form by showing how it can be used to explicate the notion of modality de re without depending on scope.
4. Extending the demonstrative notion to indefinite descriptions to see if it is possible to so explicate the ± specific idea. (It isn't.)
5. Improving (by starting all over) the analysis of the relation between Montague's treatment of indexicals and my treatment of demonstratives.
6. Showing how the treatment of proper names in the Kripke-Kaplan-Donnellan way (if there is such) is akin (?) to demonstratives.
7. Discussion of the role of common noun phrases in connection with demonstratives, as in:

(xxx) Dthat coat [the speaker points at a boy wearing a coat] is dirty.

8. Quine's contention that the content of any utterance can also be expressed by an eternal sentence. Is it true?
9. Much more to say about the phenomenology of intending to demonstrate x, and also about its truth conditions.
10. Demonstratives, dubbings, definitions, and other forms of language learning. Common nouns: what they mean and how we learn it. This section will include such pontifications as the following:

> It is a mistake to believe that normal communication takes place through the encoding and decoding of general propositions, by means of our grasp of meanings.
> It is a more serious mistake, because more pernicious, to believe that other aspects of communication can be accounted for by a vague reference to 'contextual features' of the utterance. Indeed, we first learn the

meanings of almost all parts of our language by means quite different from those of the formal definitions studied in metamathematics; and the means used for first teaching the meanings of words, rather than withering away, are regularly and perhaps even essentially employed thereafter in all forms of communication.

- Footnotes -

1. Both 'denoting concept' and 'denoting phrase' are Russell's terms used in Russell's way.

2. An example is the possibility of producing set theoretical representations of the system of natural numbers which make all even numbers alike in certain set theoretical features, (distinct from such numerical features as divisibility by two) and all odd numbers alike in other set theoretical features, or which provide simple and elegant definitions (i.e. representations) of certain basic numerical operations and relations such as less than or plus, etc.

2A. It is not too easy to single out such phrases without the help of some theory about logical form or some semantical theory. I suppose what I am after is what linguists call syntactical criteri . But I have had difficulty in finding one which will not let in phrases like "A spy". Another difficulty is connected with phrases like "John's brother" which seem to vary in their uniqueness suppositions. "John's brother is the man in dark glasses" carries, for me, the supposition that John has just one brother; whereas "The man in dark glasses is John's brother" does not. In fact the latter seems the most natural formulation when suppositions about the number of John's brothers are completely absent, since both "the man in dark glasses is one of John's brothers" and "The man in dark glasses is a brother of John's" suppose, for me, that John has more than one brother.

3. The question of whether all uses of demonstratives are accompanied by demonstrations depends on a number of factors, some empirical, some stipulative, and some in the twilight zone of theoretical ingenuity. The stipulative question is whether we use "demonstrative" to describe certain phrases which might also be described by enumeration or some such syntactical device, e.g. all phrases beginning with either "this" or "that" and followed by a common noun phrase; or whether we use "demonstrative" to describe a certain characteristic use of such phrases. In the latter case it may be stipulatively true that an utterance containing a demonstrative must be accompanied by a demonstration. In the former case, the question turns both on how people in fact speak and on how clever our theoretician is in producing recherché demonstrations to account for apparent counter-examples.

Footnotes

4. This formulation probably needs sharpening. Don't take it as a definition.

5. It should not be supposed that my practice indicates any confidence as to the nature and structure of what I call *demonstrations* or the proper form for a *demonstration-description* to take. Indeed, these are difficult and important questions which arise repeatedly in what follows.

6. From "Über Sinn und Bedeutung", emphasis added.

7. I will attempt below to press the case that this use of proper names, which involves no waving of hands or fixing of glance, may be assimilated to the more traditional forms of demonstrative use.

7A. "In the case of genuinely proper names like 'Aristotle' opinions as regards their sense may diverge. As such may, e.g., be suggested: Plato's disciple and the teacher of Alexander the Great. Whoever accepts this sense will interpret the meaning of the statement 'Aristotle was born in Stagira' differently from one who interpreted the sense of 'Aristotle' as the Stagirite teacher of Alexander the Great." From Feigl's translation of Frege's "Über Sinn and Bedeutung".

8. A third kind of indicative device is the picture. Consideration of pictures, which to me lie somewhere between pointing and describing, may help to drive home the parallels -- in terms of the distinction between the object indicated and the manner of indication -- between description, depiction, and demonstration.

9. That all utterances are in English is a general and implicit assumption except where it is explicitly called into question.

9A. "Dhe" is really a combination of the demonstrative with a common noun phrase. It stands for "Dthat male". More on such combinations below.

Footnotes

10. From Word and Object p. 193.

11. There are, of course two hidden relativizations involved even for eternal sentences. One is to a language i.e. an association of meanings with words. The Knoh — English example was meant to dramatize this relativization. The other is to a possible world. There is always the implicit reference to the actual world when we just use the expression "true". If the analogy between moments of time and possible world holds -- as some philosophers think -- then maybe we should begin our classification of sentences not with explicitly dated sentences like "In 1970 - - -" but with "Bachelors are unmarried".

12. Rather than talking directly of these functions, I should really talk first of entities like $\langle\langle$"The", S$\rangle$ P$\rangle$ and only derivatively of the functions. I will do so in the next draft.

13. This is aside from the inadequacy mentioned in the previous footnote, which continues to bother me.

14. I am still bugged by the notion of an utterance at t in w, where there is not utterance at τ in w.

15. "I" is, of course, a demonstrative; as opposed, e.g. to "the person who is uttering this utterance" which only contains the demonstrative "this utterance". Comparing utterances of

    (a) I am exhausted.

    (b) The person who is uttering this utterance is exhausted both uttered by s on the same occasion (!); To find the truth value of the content of (a) in another world w' we must determine whether s is exhausted in w', but to find the truth value of the content of (b) in w' we must first locate the same utterance in w' (if it

Footnotes

exists there at all) and see who, if anyone, is uttering it. Since $\leq$ could well be exhausted in w′ silently, the two contents are not the same.

Reference materials for 'Quantification in ordinary English'

(Richard Montague, 18 Sept 1970)

__Category indices__. Let e, t be two fixed objects (0, 1, say) that are distinct and are not ordered pairs or triples. Then CI is the smallest set X such that

(1) $e, t \in X$,

(2) whenever $A, B \in X$, A/B and $A/\!/B$ (i.e., $\langle 0, A, B\rangle$ and $\langle 1, A, B\rangle$) are also in X.

We regard e, t as the indices for entity expressions (or individual expressions) and truth value expressions (or declarative sentences) respectively.

IV (or the index for intransitive verb phrases) = t/e
CN (" common noun ") = $t/\!/e$
T (" terms) = t/IV
TV (" transitive verb ") = IV/T
IV/t is the index for sentence-taking verb phrases
IV/IV " IV-taking verb phrases
t/t " sentence-modifying adverbs
IAV (or the index for IV-modifying adverbs) = $\mathrm{IV}/\!/\mathrm{IV}$
IAV/T is the index for IAV-making prepositions

Basic sets of expressions.

$B_e = \Lambda$

$B_t = \Lambda$

B_{IV} = { **run**, **walk**, **talk**, **rise**, **change** }

B_{CN} = { **man**, **woman**, **fish**, **pen**, **unicorn**, **price**, **temperature** }

B_T = { **John**, **Mary**, **Bill**, **ninety**, $\mathbf{he}_0$, $\mathbf{he}_1$, $\mathbf{he}_2$, … }

B_{TV} = { **find**, **lose**, **eat**, **love**, **date**, **be**, **seek**, **conceive** }

$B_{IV/t}$ = { **believe that**, **assert that** }

$B_{IV/IV}$ = { **try to**, **wish to** }

$B_{t/t}$ = { **necessarily** }

B_{IAV} = { **rapidly**, **slowly**, **voluntarily**, **allegedly** }

$B_{IAV/T}$ = { **in**, **about** }

$B_A = \Lambda$ if A is any category index other than those mentioned above.

Syntactic rules.

Basic rules.

S1. $B_A \subseteq P_A$ for every category index A.

S2. If $\zeta \in P_{CN}$, then $F_0(\zeta), F_1(\zeta), F_2(\zeta) \in P_T$,
where $F_0(\zeta) =$ **every** ζ,
$F_1(\zeta) =$ **the** ζ,
$F_2(\zeta)$ is **a** ζ or **an** ζ according as the first word in ζ takes **a** or **an**.

S3. If $\zeta \in P_{CN}$ and $\phi \in P_t$, then $F_{3,n}(\zeta, \phi) \in P_{CN}$, where $F_{3,n}(\zeta, \phi) = \zeta$ **such that** ϕ' and ϕ' comes from ϕ by replacing each occurrence of $\mathbf{he}_n$ or $\mathbf{him}_n$ by $\left\{\begin{matrix}\mathbf{he}\\ \mathbf{she}\\ \mathbf{it}\end{matrix}\right\}$ or $\left\{\begin{matrix}\mathbf{him}\\ \mathbf{her}\\ \mathbf{it}\end{matrix}\right\}$ resp., according as the first B_{CN} in ζ is of $\left\{\begin{matrix}\text{masc.}\\ \text{fem.}\\ \text{neuter}\end{matrix}\right\}$ gender.

Rules of functional application.

S4. If $\alpha \in P_{t/IV}$ and $\delta \in P_{IV}$, then $F_4(\alpha, \delta) \in P_t$, where $F_4(\alpha, \delta) = \alpha\,\delta'$ and δ' is the result of replacing the first *verb* (i.e., member of B_{IV}, B_{TV}, $B_{IV/t}$, or $B_{IV/IV}$) in δ by its 3rd pers. sing. present.

S5. If $\delta \in P_{IV/T}$ and $\beta \in P_T$, then $F_5(\delta, \beta) \in IV$,
where $F_5(\delta, \beta) = \delta\beta$ if β does not have the form $\underline{he}_n$
and $F_5(\delta, \underline{he}_n) = \delta\ \underline{him}_n$.

S6. If $\delta \in P_{IAV/T}$ and $\beta \in P_T$, then $F_5(\delta, \beta) \in P_{IAV}$.

S7. If $\delta \in P_{IV/t}$ and $\beta \in P_t$, then $F_6(\delta, \beta) \in P_{IV}$,
where $F_6(\delta, \beta) = \delta\beta$.

S8. If $\delta \in P_{IV/IV}$ and $\beta \in P_{IV}$, then $F_6(\delta, \beta) \in P_{IV}$.

S9. If $\delta \in P_{t/t}$ and $\beta \in P_t$, then $F_6(\delta, \beta) \in P_t$.

S10. If $\delta \in P_{IV//IV}$ and $\beta \in P_{IV}$, then $F_7(\delta, \beta) \in P_{IV}$,
where $F_7(\delta, \beta) = \beta\delta$.

Rules of conjunction and disjunction.

S11. If $\phi, \psi \in P_t$, then $F_8(\phi, \psi), F_9(\phi, \psi) \in P_t$,
where $F_8(\phi, \psi) = \phi\ \underline{and}\ \psi$,
$F_9(\phi, \psi) = \phi\ \underline{or}\ \psi$.

S12. If $\gamma, \delta \in P_{IV}$, then $F_8(\gamma, \delta), F_9(\gamma, \delta) \in P_{IV}$.

S13. If $\alpha, \beta \in P_T$, then $F_9(\alpha, \beta) \in P_T$.

Rules of quantification.

S14. If $\alpha \in P_T$ and $\phi \in P_t$, then $F_{10,n}(\alpha, \phi) \in P_t$, where either (i) α does not have the form **he**$_k$, and $F_{10,n}(\alpha, \phi)$ comes from ϕ by replacing the first occurrence of **he**$_n$ or **him**$_n$ by α and all other occurrences of **he**$_n$ or **him**$_n$ by $\left\{\begin{matrix}\textbf{he}\\ \textbf{she}\\ \textbf{it}\end{matrix}\right\}$ or $\left\{\begin{matrix}\textbf{him}\\ \textbf{her}\\ \textbf{it}\end{matrix}\right\}$ respectively, according as the gender of the first B_{CN} or B_T in α is $\left\{\begin{matrix}\text{masc.}\\ \text{fem.}\\ \text{neuter}\end{matrix}\right\}$, or (ii) $\alpha =$ **he**$_k$, and $F_{10,n}(\alpha, \phi)$ comes from ϕ by replacing all occurrences of **he**$_n$ or **him**$_n$ by **he**$_k$ or **him**$_k$ resp.

S15. If $\alpha \in P_T$ and $\zeta \in P_{CN}$, then $F_{10,n}(\alpha, \zeta) \in P_{CN}$.

S16. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{10,n}(\alpha, \delta) \in P_{IV}$.

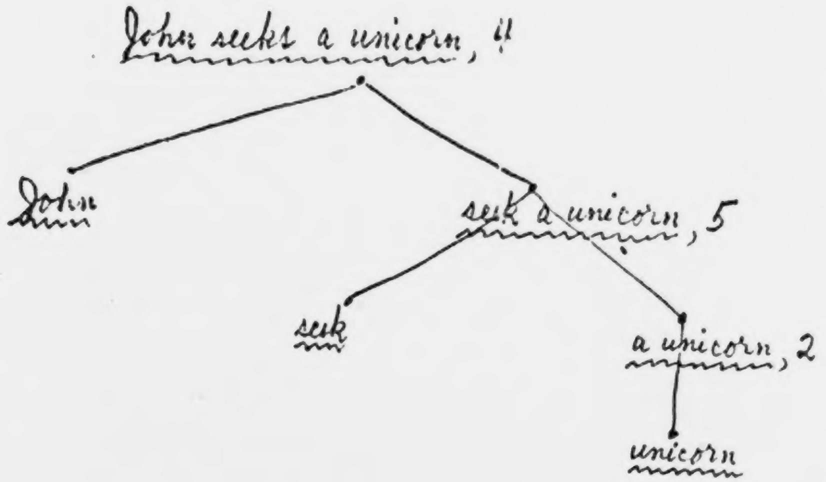
Rule of tense and sign.

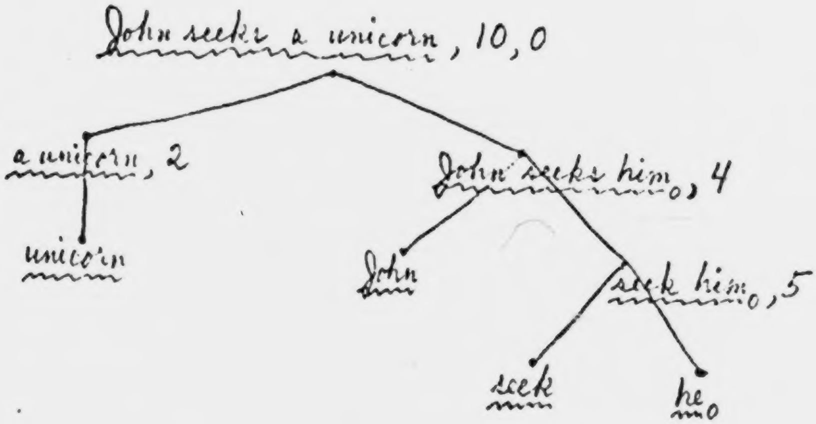
S17. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{11}(\alpha, \delta)$, $F_{12}(\alpha, \delta)$, $F_{13}(\alpha, \delta) \in P_t$, where $F_{11}(\alpha, \delta) = \alpha\delta'$ and δ' is the result of replacing the first verb in δ by its negative 3^rd^ pers. sing. present,

$F_{12}(\alpha, \delta) = \alpha\delta''$ and δ'' is the result of replacing the first verb in δ by its 3rd pers. sing. future,

$F_{13}(\alpha, \delta) = \alpha\delta'''$ and δ''' is the result of replacing the first verb in δ by its negative 3rd pers. sing. future.

Strict reconstruction. We first define certain auxiliary notions in an obvious and traditional way: the *gender* of an arbitrary member of $B_T \cup B_{CN}$, the *indefinite article taken* by an arbitrary basic expression, and the 3rd *person sing. present*, the *negative* 3rd *pers. sing. present*, the 3rd *person sing. future*, and the *negative* 3rd *person sing. future* of an arbitrary verb. Then we may regard S1 - S17 as constituting a simultaneous inductive definition of the sets $P_e, \ldots, P_{IAV/T}$. A corresponding explicit definition may be given: the sets P_A (for $A \in CI$) are the smallest sets satisfying S1 - S17; that is to say, $\langle P_A \rangle_{A \in CI}$ is the unique family of sets indexed by CI such that (1) $\langle P_A \rangle_{A \in CI}$ satisfies S1-S17, and (2) for any family $\langle P'_A \rangle_{A \in CI}$, if $\langle P'_A \rangle_{A \in CI}$ satisfies S1-S17, then $P_A \subseteq P'_A$ for all $A \in CI$.


John seeks a unicorn, 4
John
seek a unicorn, 5
seek
a unicorn, 2
unicorn


John seeks a unicorn, 10, 0
a unicorn, 2
unicorn
John seeks him$_0$, 4
John
seek him$_0$, 5
seek
he$_0$

Intensional logic.

Types. Let s be a fixed object (2, say) distinct from e and t and not an ordered pair or triple. Then Tp is the smallest set Y such that

(1) $e, t \in Y$,

(2) whenever $a, b \in Y$, $\langle a, b \rangle \in Y$,

(3) whenever $a \in Y$, $\langle s, a \rangle \in Y$.

Meaningful expressions.

$v_{n,a}$: the $n^{\underline{th}}$ variable of type a

Con_a : the set of constants of type a

(Con_a is assumed to be infinite.)

ME_a (or the set of meaningful expressions of type a) has the following recursive definition:

(1) Every variable and constant of type a is in ME_a.

(2) If $\alpha \in ME_a$ and u is a var. of type b, then $\lambda u \alpha \in ME_{\langle b, a \rangle}$.

(3) If $\alpha \in ME_{\langle a, b \rangle}$ and $\beta \in ME_a$, then $\alpha(\beta) \in ME_b$.

(4) If $\alpha, \beta \in ME_a$, then $\alpha = \beta \in ME_t$.

(5) If $\phi, \psi \in ME_t$ and u is a variable, then $\neg \phi$, $[\phi \wedge \psi]$, $[\phi \vee \psi]$, $[\phi \rightarrow \psi]$, $[\phi \leftrightarrow \psi]$, $\bigvee u \, \phi$, $\bigwedge u \, \phi$, $\Box \phi$, $W \phi$, $H \phi \in ME_t$.

(6) If $\alpha \in ME_a$, then $[{}^\wedge \alpha] \in ME_{\langle s, a \rangle}$.

(7) If $\alpha \in ME_{\langle s, a \rangle}$, then $[{}^\vee \alpha] \in ME_a$.

(In the interests of perspicuity square brackets will sometimes be omitted, and sometimes gratuitously inserted.)

Possible denotations and senses. Let A, I, J be any sets; they may be regarded as the sets of entities (or individuals), possible worlds, and moments of time resp. Then $D_{a, A, I, J}$ (or the set of possible denotations of type a corresponding to A, I, J) has the following recursive def.:

$$D_{e, A, I, J} = A,$$

$$D_{t, A, I, J} = \{0, 1\} = \{\text{falsehood}, \text{truth}\},$$

$$D_{\langle a, b \rangle, A, I, J} = D_{b, A, I, J}^{D_{a, A, I, J}},$$

$$D_{\langle s, a \rangle, A, I, J} = D_{a, A, I}^{I \times J}.$$

$S_{a, A, I, J}$ (or the set of senses of type a corr. to A, I, J) $= D_{a, A, I, J}^{I \times J}$.

Interpretations. These are quintuples $\langle A, I, J, \leq, F \rangle$ such that (1) A, I, J are nonempty sets,

(2) $\leq$ is a simple (i.e., linear) ordering of J,

(3) F is a function having as its domain the set of all constants,

(4) whenever $\alpha \in Con_a$, $F(\alpha) \in S_{a,A,I,J}$.

Intension and extension. Suppose that $\mathfrak{A} = \langle A, I, J, \leq, F \rangle$ and that g is an $\mathfrak{A}$-assignment (of values to variables), that is, a function such that $g(u) \in D_{a,A,I,J}$ whenever u is a variable of type a. If $\alpha \in \bigcup_{a \in T_p} ME_a$, we understand by $\alpha^{\mathfrak{A},g}$ the intension of α with respect to $\mathfrak{A}$ and g; and if $\langle i,j \rangle \in I \times J$, then $\alpha^{\mathfrak{A},i,j,g}$ is to be the extension of α with respect to $\mathfrak{A}$, i, j, and g — that is, $\alpha^{\mathfrak{A},g}(\langle i,j \rangle)$. Recursive def.

(1) If α is a constant, then $\alpha^{\mathfrak{A},g}$ is $F(\alpha)$.

(2) If α is a variable, then $\alpha^{\mathfrak{A},i,j,g}$ is $g(\alpha)$.

(3) If $\alpha \in ME_a$ and u is a var. of type b, then $[\lambda u \alpha]^{\mathfrak{A},i,j,g}$ is that function h with domain $D_{b,A,I,J}$ such that

whenever x is in that domain, h(x) is $\alpha^{\mathfrak{A},i,j,g'}$, where g' is the assignment like g except for the possible difference that $g'(u)$ is x.

(4) If $\alpha \in ME_{\langle a,b \rangle}$ and $\beta \in ME_a$, then $[\alpha(\beta)]^{\mathfrak{A},i,j,g}$ is $\alpha^{\mathfrak{A},i,j,g}(\beta^{\mathfrak{A},i,j,g})$.

(5) If $\alpha, \beta \in ME_a$, then $[\alpha = \beta]^{\mathfrak{A},i,j,g}$ is 1 iff $\alpha^{\mathfrak{A},i,j,g}$ is $\beta^{\mathfrak{A},i,j,g}$.

(6) If $\phi \in ME_t$, then $[\neg \phi]^{\mathfrak{A},i,j,g}$ is 1 iff $\phi^{\mathfrak{A},i,j,g}$ is 0; and similarly for $\wedge$, $\vee$, $\rightarrow$, $\leftrightarrow$.

(7) If $\phi \in ME_t$ and u is a var. of type a, then $[\bigvee u\, \phi]^{\mathfrak{A},i,j,g}$ is 1 iff there exists $x \in D_{a,A,I,J}$ such that $\phi^{\mathfrak{A},i,j,g'}$ is 1, where g' is as in (3); and similarly for $\bigwedge u\, \phi$.

(8) If $\phi \in ME_t$, then $[\Box \phi]^{\mathfrak{A},i,j,g}$ is 1 iff $\phi^{\mathfrak{A},i',j',g}$ is 1 for all $i' \in I$ and $j' \in J$; $[W \phi]^{\mathfrak{A},i,j,g}$ is 1 iff $\phi^{\mathfrak{A},i,j',g}$ is 1 for some j' such that $j \leq j'$ and $j \neq j'$; and $[H \phi]^{\mathfrak{A},i,j,g}$ is 1 iff $\phi^{\mathfrak{A},i,j',g}$ is 1 for some j' such that $j' \leq j$ and $j' \neq j$.

(9) If $\alpha \in ME_a$, then $[{}^\wedge\alpha]^{\mathfrak{A},i,j,g}$ is $\alpha^{\mathfrak{A},g}$.

(10) If $\alpha \in ME_{\langle s,a\rangle}$, then $[{}^\vee\alpha]^{\mathfrak{A},i,j,g}$ is $\alpha^{\mathfrak{A},i,j,g}(\langle i,j\rangle)$.

If ϕ is a formula (i.e., member of ME_t), then ϕ is true with respect to $\mathfrak{A}, i, j$ if and only if $\phi^{\mathfrak{A},i,j,g}$ is 1 for every $\mathfrak{A}$-assignment g.

Some special expressions.

If $\gamma \in ME_{\langle a,t\rangle}$ and $\alpha \in ME_a$, then γ denotes (i.e., has as its extension) a set (or really the characteristic fun. of a set), and we may regard the formula $\gamma(\alpha)$ as asserting that the object denoted by α is a member of that set.

If $\gamma \in ME_{\langle a,\langle b,t\rangle\rangle}$, $\alpha \in ME_a$, and $\beta \in ME_b$, then γ may be regarded as denoting a (2-place) relation, and $\gamma(\beta, \alpha)$ is to be the expression $\gamma(\alpha)(\beta)$, which asserts that the objects denoted by β and α stand in that relation.

If $\gamma \in ME_{\langle s,\langle a,t\rangle\rangle}$ and $\alpha \in ME_a$, then γ denotes a property, and $\gamma\{\alpha\}$ is to be the expression $[{}^\vee\gamma](\alpha)$, which asserts that the object denoted by α has that property.

If $\gamma \in ME_{\langle s, \langle a, \langle b, t \rangle\rangle\rangle}$, $\alpha \in ME_a$, and $\beta \in ME_b$, then γ may be regarded as denoting a *relation-in-intension*, and $\gamma\{\beta, \alpha\}$ is to be the expression $[{}^\vee\gamma](\beta, \alpha)$, which asserts that the objects denoted by β and α stand in that relation-in-intension.

If u is a variable of type a and ϕ a formula, then $\hat{u}\phi$ is to be $\lambda u \phi$, which denotes the set of all objects of type a that satisfy ϕ (with respect to the place marked by u), and $\hat{u}\phi$ is to be $[{}^\wedge \hat{u}\phi]$, which denotes the property of objects of type a expressed by ϕ.

If $\alpha \in ME_e$, then α^* is to be $\hat{P}[P\{{}^\wedge\alpha\}]$.

If $\delta \in ME_{\langle\langle s, e\rangle, t\rangle}$, then δ_* is to be $\hat{u}\,\delta({}^\wedge u)$.

Translation of English into intensional logic

Let $f(e) = e$,

$f(t) = t$,

$f(A/B) = f(A/\!/B) = \langle\langle s, f(B)\rangle, f(A)\rangle$ whenever $A, B \in CI$.

Let g be a fixed 1-1 function mapping the basic expressions of our fragment of English other than **be**, **necessarily**, and the members of B_T onto constants of intensional logic, and such that whenever $A \in CI$, $\alpha \in B_A$, and α is in the domain of g, $g(\alpha) \in Con_{f(A)}$.

Let j, m, b, n be particular distinct members of Con_e.

Basic rules (of translation)

T1. (a) If α is in the domain of g, then α tr $g(\alpha)$.

(b) **be** tr $\lambda \mathcal{P} \lambda x\, \mathcal{P}\{\hat{y}[{}^\vee x = {}^\vee y]\}$, where $x, y, \mathcal{P}$ are $v_{1,\langle s,e\rangle}$, $v_{3,\langle s,e\rangle}$, $v_{0,\langle s,\langle\langle s,\langle\langle s,e\rangle,t\rangle\rangle,t\rangle\rangle}$ resp.

(c) **necessarily** tr $\hat{p}[\Box p]$, where $p = v_{0,\langle s,t\rangle}$.

(d) **John** tr $\hat{P}\, P\{{}^\wedge j\}$, **Mary** tr $\hat{P}\, P\{{}^\wedge m\}$, **Bill** tr $\hat{P}\, P\{{}^\wedge b\}$, **ninety** tr $\hat{P}\, P\{{}^\wedge n\}$, where $P = v_{0,\langle s,\langle\langle s,e\rangle,t\rangle\rangle}$.

(e) **he**$_n$ tr $\hat{P}\, P\{x_n\}$, where $x_n = v_{2n,\langle s,e\rangle}$.

T2. If $\zeta \in P_{CN}$ and ζ tr ζ', then

$\underset{\sim}{\text{every}}\ \zeta$ tr $\hat{P} \bigwedge x[\zeta'(x) \to P\{x\}]$,

$\underset{\sim}{\text{the}}\ \zeta$ tr $\hat{P} \bigvee y[\bigwedge x[\zeta'(x) \leftrightarrow x = y] \wedge P\{y\}]$,

$F_2(\zeta)$ tr $\hat{P} \bigvee x[\zeta'(x) \wedge P\{x\}]$.

T3. If $\zeta \in P_{CN}$, $\phi \in P_t$, and ζ, ϕ tr ζ', ϕ', then

$F_{3,n}(\zeta, \phi)$ tr $\hat{x}_n[\zeta'(x_n) \wedge \phi']$ (where x_n is as above).

Rules of functional application.

T4. If $\delta \in P_{t/IV}$, $\beta \in P_{IV}$, and δ, β tr δ', β', then $F_4(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

T5. If $\delta \in P_{IV/T}$, $\beta \in P_T$, ″ , then $F_5(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

T6. If $\delta \in P_{IAV/T}$, $\beta \in P_T$, ″ , then $F_5(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

T7. If $\delta \in P_{IV/t}$, $\beta \in P_t$, ″ , then $F_6(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

T8. If $\delta \in P_{IV/IV}$, $\beta \in P_{IV}$, ″ , then $F_6(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

T9. If $\delta \in P_{t/t}$, $\beta \in P_t$, ″ , then $F_6(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

T10. If $\delta \in P_{IV//IV}$, $\beta \in P_{IV}$, ″ , then $F_7(\delta, \beta)$ tr $\delta'({}^\wedge\beta')$.

Rules of conjunction and disjunction.

T11. If $\phi, \psi \in P_t$ and ϕ, ψ tr ϕ', ψ', then $\phi \ \underset{\sim}{\text{and}}\ \psi$ tr $[\phi \wedge \psi]$,

$\phi \ \underset{\sim}{\text{or}}\ \psi$ tr $[\phi \vee \psi]$.

T12. If $\gamma, \delta \in P_{IV}$ and γ, δ tr γ', δ', then γ **and** δ tr $\hat{x}[\gamma'(x) \wedge \delta'(x)]$,
γ **or** δ tr $\hat{x}[\gamma'(x) \vee \delta'(x)]$.

T13. If $\alpha, \beta \in P_T$ and α, β tr α', β', then α **or** β tr $\hat{P}[P\{\alpha'\} \vee P\{\beta'\}]$.

Rules of quantification.

T14. If $\alpha \in P_T$, $\phi \in P_t$, and α, ϕ tr α', ϕ', then $F_{10,n}(\alpha, \phi)$ tr $\alpha'(\hat{x}_n \phi')$ (where x_n is as above).

T15. If $\alpha \in P_T$, $\zeta \in P_{CN}$, and α, ζ tr α', ζ', then $F_{10,n}(\alpha, \zeta)$ tr $\hat{y}\, \alpha'(\hat{x}_n[\zeta'(y)])$.

T16. If $\alpha \in P_T$, $\delta \in P_{IV}$, and α, δ tr α', δ', then $F_{10,n}(\alpha, \delta)$ tr $\hat{y}\, \alpha'(\hat{x}_n[\delta'(y)])$.

Rules of tense and sign.

T17. If $\alpha \in P_T$, $\delta \in P_{IV}$, and α, δ tr α', δ', then
$F_{11}(\alpha, \delta)$ tr $\neg \alpha'(\hat{\ }\delta')$,
$F_{12}(\alpha, \delta)$ tr $W\alpha'(\hat{\ }\delta')$,
$F_{13}(\alpha, \delta)$ tr $\neg W\alpha'(\hat{\ }\delta')$.

Strict reconstruction. We may define tr as the smallest binary relation satisfying T1–T17.

Logical notions

The following formulas are true in the intended interpretation of intensional logic:

(1) $\bigvee u \, \Box [u = \alpha]$, where α is j, m, b, or n, and u is $v_{0,e}$,

(2) $\Box [\delta(x) \rightarrow \bigvee u \; x = {}^\wedge u]$, where δ translates any member of B_{IV} or B_{CN} other than *rise*, *change*, *price*, or *temperature*,

(3) $\Box [\delta(x, \mathcal{P}) \rightarrow \bigvee u \; x = {}^\wedge u]$, where δ translates any member of B_{TV} other than *be*,

(4) $\Box [\delta(x, p) \rightarrow \bigvee u \; x = {}^\wedge u]$, where δ translates *believe that* or *assert that*,

(5) $\Box [\delta(x, P) \rightarrow \bigvee u \; x = {}^\wedge u]$, where δ translates *try to* or *wish to*,

(6) $\bigvee S \bigwedge x \bigwedge \mathcal{P} \, \Box [\delta(x, \mathcal{P}) \leftrightarrow \bigvee u [x = {}^\wedge u \wedge \mathcal{P}\{\hat{y} \bigvee v [y = {}^\wedge v \wedge S\{u, v\}]\}]]$, where δ translates *find*, *lose*, *eat*, *love*, or *date* and S is $v_{0, \langle s, \langle e, \langle e, t \rangle\rangle\rangle}$,

(7) $\Box [\text{seek}'(x, \mathcal{P}) \leftrightarrow \text{try-to}'(x, {}^\wedge[\text{find}'(\mathcal{P})])]$, where *seek*$'$, *try-to*$'$, *find*$'$ translate *seek*, *try to*, *find*,

(8) $\bigvee G \bigwedge \mathcal{P} \bigwedge Q \bigwedge x \, \Box [\delta(\mathcal{P})(Q)(x) \leftrightarrow \mathcal{P}\{\hat{y} \bigvee u [y = {}^\wedge u \wedge G(u)(Q)(x)]\}]$, where δ translates *in*, Q is $v_{1, \langle s, \langle\langle s, e \rangle, t \rangle\rangle}$, and G is $v_{0, \langle s, \langle e, f(IAV) \rangle\rangle}$.

By a *logically possible interpretation* of intensional logic understand one in which (1) -(8) are true (w.r.t to all, or equivalently any, worlds and moments of time). Logical truth, logical consequence, logical equivalence (for formulas of intensional logic) are to be characterized accordingly.

Examples. '——' means 'translates into some formula logically equivalent to'. It is assumed that basic expressions of English translate into their primed variants below.

Bill walks — $\mathbf{walk}'_{*}(b)$

a man walks — $\bigvee u\,[\mathbf{man}'_{*}(u) \wedge walk'_{*}(u)]$

every man walks — $\bigwedge u\,[\mathbf{man}'_{*}(u) \rightarrow walk'_{*}(u)]$

the man walks — $\bigvee v \bigwedge u\,[[\mathbf{man}'_{*}(u) \leftrightarrow u = v] \wedge \mathbf{walk}'_{*}(v)]$

John finds a unicorn — $\bigvee u\,[\mathbf{unicorn}'_{*}(u) \wedge \mathbf{find}'({}^{\wedge}j, {}^{\wedge}u^{*})]$

John seeks a unicorn $< \begin{array}{l} \mathbf{seek}'({}^{\wedge}j,\ \hat{P} \bigvee u\,[\mathbf{unicorn}'_{*}(u) \wedge P\{{}^{\wedge}u\}]) \\ \bigvee u\,[\mathbf{unicorn}'_{*}(u) \wedge \mathbf{seek}'({}^{\wedge}j, {}^{\wedge}u^{*})] \end{array}$

John tries to find a unicorn

$$\underline{\text{try-to}}'({}^\wedge j, \hat{y} \bigvee u \bigvee v[\underline{\text{unic}}'_*(u) \wedge y = {}^\wedge v \wedge \underline{\text{find}}'({}^\wedge v, {}^\wedge u^*)])$$

$$\bigvee u[\underline{\text{unicorn}}'_*(u) \wedge \underline{\text{try-to}}'({}^\wedge j, {}^\wedge \underline{\text{find}}'({}^\wedge u^*))]$$

Bill is Mary — $b = m$

Bill is a man — $\underline{\text{man}}'_*(b)$

the temperature is ninety — $\bigvee y[\bigwedge x[\underline{\text{temp}}'(x) \leftrightarrow x = y] \wedge [{}^\vee y] = n]$

the temperature rises — $\bigvee y[$ " $\wedge\, \underline{\text{rise}}'(y)]$

ninety rises — $\underline{\text{rise}}'({}^\wedge n)$

a price rises — $\bigvee x[\underline{\text{price}}(x) \wedge \underline{\text{rise}}(x)]$

a woman loves every man

$$\bigvee u[\underline{\text{woman}}'_*(u) \wedge \bigwedge v[\underline{\text{man}}'_*(v) \to \underline{\text{love}}'({}^\wedge u, {}^\wedge v^*)]]$$

$$\bigwedge v[\underline{\text{man}}'_*(v) \to \bigvee u[\underline{\text{woman}}'_*(u) \wedge \underline{\text{love}}'({}^\wedge u, {}^\wedge v^*)]]$$

John seeks a unic. and Mary seeks it — $\bigvee u[\underline{\text{unic}}'_*(u) \wedge \underline{\text{seek}}'({}^\wedge j, {}^\wedge u^*) \wedge \underline{\text{seek}}'({}^\wedge m, {}^\wedge u^*)]$

John wishes to find a unicorn and eat it

$$\bigvee u[\underline{\text{unic}}'_*(u) \wedge \underline{\text{wish-to}}'({}^\wedge j, \hat{y} \bigvee v[y = {}^\wedge v \wedge \underline{\text{find}}'({}^\wedge v, {}^\wedge u^*) \wedge \underline{\text{eat}}'({}^\wedge v, {}^\wedge u^*)])]$$

$$\underline{\text{wish-to}}'({}^\wedge j, \hat{y} \bigvee u \bigvee v[\underline{\text{unic}}'_*(u) \wedge y = {}^\wedge v \wedge \underline{\text{find}}'({}^\wedge v, {}^\wedge u^*) \wedge \underline{\text{eat}}'({}^\wedge v, {}^\wedge u^*)])$$

John wishes to find a unic. and tries to eat it

$$\longrightarrow \bigvee u\,[\underset{\sim}{\text{unic}}'_*(u) \wedge \underset{\sim}{\text{wish-to}}'({}^\wedge j, \hat{y}\,\bigvee v\,[y = {}^\wedge v \wedge \underset{\sim}{\text{find}}'({}^\wedge v, {}^\wedge u^*)]) \wedge \underset{\sim}{\text{try-to}}'({}^\wedge j, \hat{y}\,\bigvee v\,[y = {}^\wedge v \wedge \underset{\sim}{\text{eat}}'({}^\wedge v, {}^\wedge u^*])]$$

Mary believes that John finds a unicorn and he eats it $<$

(equivocal)

Mary believes that John finds a unicorn and asserts that he eats it ——

(univocal)

Mary asserts that John finds a unic. and believes that he eats it ——

(univocal)

THE PROBLEM OF THE SEMANTICS OF MASS TERMS IN ENGLISH

Both linguists and philosophers recognize that terms like 'dirt', 'water', 'iron', etc. differ in behaviour from those like 'table', 'star', 'man', etc. The differences have been coded at times in synatctic and at times in semantic terms, but at present we lack a comprehensive account. Let us consider the first class under the description 'mass terms'[1]. We can then characterize the task of this paper as the exploration of the semantics and syntax of mass terms, and the raising of the issue of how an adequate treatment could be incorporated into a general theory of English.

What is a mass term? Though there is general agreement in terms of examples, there exists no generally accepted and comprehensive definition of what a mass term is. In recent times the notion can be found - as count- - in Chomksy's subcategorization system[2]. Chomsky places this class under the headings of noun, common, and contrasts it not only with concrete count nouns, but also with all abstract terms, and with animate terms. Thus according to this provisional classification all mass terms are common concrete inanimate nouns. Though this classification captures the class of terms that would be used normally as paradigms, it is not clear what the syntactic criteria would be in terms of which this class and this class only could be identified. A further attempt at delineation is given in Parsons' paper[3]. This account is like Chomsky's in that it considers all mass terms nouns, but in its search for at least rough criteria it expands the class under consideration. The two criteria that Parsons recommends are: mass terms do not admit of pluralization, and when they are used in the required sense they can be preceded by 'much'. Parsons recognizes exceptions to the first criterion, namely 'potatoes', or 'beans' in the sense of "what do we have for lunch? Potatoes.". Reflexion on these criteria leads Parsons to the correct conclusion that taking these as decisive shows some mass terms - like 'speed', or 'information' - to be not concrete.

A more detailed attempt at giving a sound characterization than either of the two mentioned so far is to be found in Quine's work[4]. His characterization is partly syntactic and partly semantic. Syntactically, he likens mass terms to singular terms in so far as both kinds of expressions resist pluralization and articles. Semantically they are distinguished by having the property of cumulative reference. That is to say, e.g. "any sum of parts which are water is water". In general, if 'w' is a mass term, then any sum of parts that are *w* is itself *w*. For Quine the semantic characterization is more important. Though his further suggestions are not in conflict with the syntactic characterization (as long as one takes these as not necessary conditions) it is the semantic characterization that leads him to point out that since the separation into noun and adjective has little to do with questions of reference, mass terms should not be construed as including nouns only. Quine's characterization, in terms of cumulative reference, fits a large class of adjectives as well as it fits nouns. For example, any sum of parts that are red is itself red. Thus Quine proposes[5] that the "term with divided reference vs. mass term" distinction (which is equivalent to the count+- distinction as used by linguists) be extended to cover adjectives as well..Color terms e obviously mass adjectives according to this division, and Quine mentions 'spherical' as an example of an adjective that divides its reference and thus would have to be marked as count+ by the linguist. The extension of the distinction to cover adjectives is made purely on the basis of the semantic criterion. Indeed, it is an interesting question of the study of this topic as to whether one can find relevant syntactic distinctions among adjectives that would mirror the division that Quine makes solely on semantic grounds. To complete this brief summary of Quine's views we must add that Quine emphasizes what he takes to be the dual role of mass terms. They can appear either before or after the 'is' of predication; e.g. 'water is a liquid', and 'that puddle is water'. This dual role in terms of grammatical roles is given an important function in Quine's proposed semantics for mass terms.

The extension of count+- to abstract terms is one of the key features of the proposed revision of the subcategorization system by Moravcsik[6]. In this proposal abstract count nouns like 'virtue', 'colour', 'science', and 'objection' are contrasted with such abstract mass terms as 'nonsense', 'fuzziness', 'vagueness', 'precision', 'significance', etc. Among the differentiations proposed we find again the matter of taking and not taking articles as well as pluralization respectively, and two additional points. One of these is that of items denoted by count+ expressions we can ask "how many?" while we cannot ask: "how much?". In the case of mass terms we find the reverse situation. e other differentiation proposed is in terms of co-occurrence restrictions. It is claimed that some adjectives such as 'numerous' can go with count+ nouns but not with count- expressions. It is also claimed a verb like 'count' can take as object only something denoted by count+ expressions. An analogous distinction holds with regard to subjects that verbs can take. Thus, e.g., 'walks' or 'think' must have count+ as subject (I do not share the claim that some linguist made that the subject of such a verb must be classified animate) while a verb like 'flow', or 'melt' can take count-, or mass terms, as subject.

In addition to this way of classifying verbs in connection with the count+- dichotomy, it may be that an even sharper division is possible. According to a recent proposal made by G.N. Leech verbs can be divided on purely semantic ground into count+- depending on whether the verb denotes events or a state[7]. Verbs like 'kick', 'open', 'start', and 'fall' denote events according to Leech and are thus classified as count+ and contrasted with those verbs that denote states. (E.g. 'enjoy').

Having summarized these proposals, let us turn to some critical remarks. If one agrees with Quine that some adjectives are also mass terms, then the fact that Parsons' suggested mark does not apply to adjectives will be regarded as a flaw in that account. (Parsons himself regards only nouns as candidates for mass terms; he does not discuss the facts that lead Quine to take the other position. hus one might try to take Quine's purely semantic criterion as the decisive mark of mass terms. It seems to me, however, that we encounter two difficulties here. One of these is the application of the criterion to all adjectives. Consider 'large' and 'small' and then again 'heavy' and 'light'. Both 'large' and 'heavy' seem to qualify as mass terms according to Quine's semantic criterion. For the sum of any parts that are large - or heavy - is itself large, or heavy. We would expect then to have 'small' and 'light' also to behave as mass terms; but it is not clear that they meet Quine's condition. Is the sum of any parts that are small or light respectively itself small or light? Perhaps one could rule out these examples on the ground that these adjectives admit the comparative form; thus we have heavier, lighter, smaller, taller, etc. One might propose that terms admitting the comparative form are not mass terms, but always implicit dyadic predicates. It is not clear how satisfactory this proposal would be since the colour terms too seem to admit in some sense comparatives. Could not one thing be more red or more blue than another? In order to defend Quine's proposal along the lines suggested above, these locutions will have to be explained, or, rather, explained away.

The other difficulty is encountered when we try to apply Quine's criterion to abstract mass terms. This is not Quine's difficulty, one might say, since he does not advocate such applications. For mass terms are defined in terms of mereological concepts. (More on these later.) But it is not clear how one applies notions like 'part', 'sum', and 'overlap' to abstract entities; nor is it clear that when in the use of ordinary English such applications are made, that these reflect the senses intended when the terms are applied to concrete entities. This difficulty can be taken as one that affects proposals such as my earlier one referred to above. But if that proposal is abandoned, some other way must be found to accounting for the syntactic similarities that cut across the abstract - concrete dichotomy. Another flaw of my proposal is that it does not answer the following two questions that are relevant to assessing the claims made about co-occurrence relations between verbs and subject expressions to which the count+- distinction is relevant. One of these questions is: what is the full range of verbs that require count+ subjects without these being marked as animate? The examples mentioned, such as 'think' or 'believe' are not beyond controversy. Perhaps examples like 'write', 'work', 'function', will turn out to be more persuasive. The other question is: are there any verbs that require as their subject a mass term? The examples quoted above, such as 'melt' and 'flow' are verbs that can take either count+ or count- subjects; ice melts, but so can statues, and water flows but so do rivers. It would be interesting to show either that there are verbs that must have mass subjects, or that any verb that can take a mass subject can take also a count+ subject.

Let us briefly summarize the current state of work on the topic under consideration. The atte to give a general definition of what a mass term is encounters four problems. First, there is the question of whether to construe mass terms as a set of nouns, or to extend the classification to cover adjectives and verbs as well. Decision on this matter clearly depends on finding adequate criteria for each syntactic class and finding sufficiently important common elements among these to warrant a more inclusive delineation. Secondly, there is the problem of whether mass terms should be restricted to those that have concrete entities as elements of their denotation or not. By 'concrete' in this context we mean 'that which has spatio-temporal location, is extended, and can be observed by the senses'. Again, the decision will depend on the availability of criteria; either syntactic, or in terms of an adequate interpretation of mereological notions for abstract entities. The third problem is that of finding general and reliable syntactic criteria. The extent of generality depends on the choices made with regard to the two problems mentioned above. We saw that pluralization is not a water-tight criterion, and suggestions such as the addition of 'much' 'quantity of' as well as the question: "how much?" cover only items in the category noun. There are no proposals for the syntactic classification of adjectives along these lines, and Leech's very recent suggestions concerning verbs requires further study. The fourth problem is that of finding a general semantic characterization, again depending on the delineation chosen. The most promising line seems to be the further extension of Quine's criterion. For example, it would be worth investigating what connections there are between Leech's distinction of events and states, and Quine's distinction between cumulative and divided reference.

Before we leave this topic two points need to be made. So far we talked about the distinction at issue as one between two classes of expressions. This is, however, an oversimplificatio It has been pointed out by Quine[8], Cartwright[9], and Parsons[10], that many terms have both a count+ as well as a count- sense, or type of application. E.g. 'I drank some water', and '...from the land of the sky-blue waters', or 'I ate some chicken', and 'I chased a chicken'. This raises some questi that are of interest to the linguist as well as those philosophers who are concerned with the structure of a lexicon. The difference under consideration cannot be assimilated to the normal use of "difference in sense" or ambiguity. On the other hand, one can hardly list the relevant pairs as tw independent and unrelated items in the dictionary. The situation is analogous to the one holding between abstract singular terms and the corresponding general terms (e.g. 'chaste' and 'chastity').

Finally, a word about the need and utility of mass terms. Quine seems to suggest[11] that this is an "archaic category", not very suitable to more sophisticated discoutse, mirroring the semantics of the child's early vocabulary. It seems to me that this observation should be supplemented by the realization that it is the availability of mass terms that allows the quantitative analysis of concepts and thus the growing sophistication of the applied sciences. Roughly speaking terms with count+ specification invite qualitative analysis (we don't measure men, or tables, but we do measure length, weight, etc.) while mass terms invited quantitative analysis. It is difficult - if not impossible - to conceive of the language of the sciences without mass terms. Needless to say, this is accompanied by measurement and the concepts of number, while in the child's early use of mass terms these additional notions do not yet emerge.

Proposals for the Semantics of Mass Terms. The most detailed proposal for the semantics of mass terms has been made by Quine. As was pointed out above, a mass term, according to this proposal, refers cumulatively. This means that the mass term 'water' refers to that individual that is scattered through time and place and whose parts are all the water that ever was, is, and will be. The reference, or denotation, of all mass terms is to be understood in the same way. The objects referred to are to be understood according to the calculus of individuals, as explained e.g. by N. Goodman[12]. The various relations as well as distinctness of individuals can be explained and defined rigorously within this system with the aid of the primitive 'overlap', symbolized by 'o'. This allows us to generate the reference of complex mass terms out of the references of their parts. For example the reference of 'wood furniture' is the individual the parts of which are the overlappi parts of the individual wood and the individual furniture. The reference of 'water and iron' will be the sum of the individual water and the individual iron.

This account of the reference of mass terms is, however, qualified by Quine with the help of grammatical notions. For the interpretation summarized above applies to mass terms only when these are in subject position, or - as Quine puts it - before the 'is' of predication[13]. Quine proceeds to suggest that the "simplest plan" is to treat the mass term as described when before the 'is', but as a general term when it is after the 'is' of predication. It is difficult to give an adequate interpretation of this suggestion as it stands. What is it to treat a word 'w' some times as a singular term, and in other contexts as a general term? So far we have been given only an interpretatio of the semantics of these terms when they function as singular terms; if we are to interpret them in some contexts as general terms, what are the entities that these terms are true of? E.g. what is 'water' true of when used as a general term? The paragraph following[14] suggests the interpretation that according to Quine mass terms when used as general terms are elliptical. For he suggests that 'is sugar' and 'is furniture' (as e.g. in 'the white part is sugar' and 'the rest of the cargo is furniture') should be read as 'is a bit of sugar' and 'is a batch of furniture' respectively. According to this interpretation Quine does not really mean that e.g. 'water' can be both a singular term and a general term, but rather, that 'water' is a mass term when in subject position, and when in predicate position, then it is always a part of some complex predicate expression such as 'bit of...', 'batch of...' etc. Thus in the full analysis no mass term is also construable as a general term, but rather as a part of a collection of complex general terms. This interpretation of the proposal makes reasonably good sense; the merits of the proposal would then depend on how well we can account for expressions like 'bit of water' as general terms. Unfortunately, it is not clear that this interpretation of Quine's proposal is sound. For in the same paragraph he writes also: "...in general a mass term in predicative position may be viewed as a general term which is true of each portion of the stuff in question...". This does not sound as if it construed mass terms in predicative positions as elliptical. I fail, however, to make much sense of a term being "true of each portion". What is the definition of 'portion'? What are criteria of identity? How many portions of stuff are there, e.g. of water? Of course, if this sentence about portions is merely a short-hand for a [illegible] group of complex general terms, then this sentence is in harmony with the interpretation of Quine's proposal given above. If it is not, its exact meaning remains unclear to at least one reader.

It is not a trivial task to find out what Quine means by "treating a mass term as a general term", since it figures in several parts of Quine's proposal. For example, when he turns to the consideration of a complex formed by the demonstrative 'this' and a mass term Quine again recommend treating the mass term as a general term[15]. Again, however, we are given a paraphrase. " 'Water' so used amounts to the general term 'body of water' ". In harmony with the above, I take Quine to be saying that in the combination Demonstrative+Mass Term, the latter is elliptical, and is to be read in fully analyzed form as part of a complex general term. (Bodies of water - unlike portions - do have relatively clear criteria of identity through time and space; the reason for this is that 'body', unlike 'portion', is clearly count+.)

As noted above, Quine regards some adjectives also as mass terms. His treatment of these is analogous to the treatment of the corresponding nouns. Thus 'red' refers to that scattered individual that has as its parts all that ever was, is or will be red. The "computation of complexes" parallels that of complex noun expressions, and apparently so does the treatment of adjectives depending whether these are in subject of predicate position. This last analogy, however, seems not to be without difficulties. If my interpretation of Quine's proposal is correct, then in 'some black bears are brown' 'brown' is to be treated as a general term, since it comes after the 'is' of predication. We saw above, however, that this amounts to saying that 'brown' in this context is elliptical; it is really part of a complex general term. I find it difficult to supply the required general term. Will 'bit of brown' fit here? If, on the other hand, 'brown' in the sentence cited is to be treated by itself as a general term, it is not clear what the entities are that this term is true of.

The most interesting part of Quine's treatment of adjectives[16] - and presumably part of the rationale of the proposal - is his construal of the semantics of complex noun phrases that are made up of noun and adjective. In a complex in which the noun is count+ such as 'red house' Quine proposes to treat 'red' as a general term, and thus, of course, the whole noun phrase as count+. In cases where the adjective modifies a noun that is a mass term, Quine proposes to treat the adjective also as a mass term, and the whole complex in the same way. Quine hypothesizes that adjectives that are not mass terms, such as e.g. 'spherical' will never modify a noun that is a mass term. One might summarize these suggestions by saying that in computing the semantics of an NP that is N and Adj, the noun dominates and determines the interpretation of the adjective as well as the whole complex.

The dual treatment of mass terms may strike one as odd, and so would the remark that this is the "simplest" plan. But there are good reasons for both claims. For Quine does take up the possibility of a unified treatment of the semantics of mass terms such that they would refer cumulatively regardless of grammatical role. This would involve treating the copula as ambiguous; in 'this object is a statue' the 'is' stands for class membership, while in 'the white part is sugar' the 'is' would stand for the 'is a part of' relation as explained in terms of the calculus of individuals. Quine thinks that the mereological interpretation fails because not all parts of water, sugar, etc, are water, sugar, etc.[17]. Moreover, Quine sees that there is no general rule for all mass terms that determines which parts are too small to count as a part that is still referred to by the name of the substance in question. E.g. consider the parts that are no longer water, and the parts that are no longer furniture, the parts that are no longer snow, etc.. Thus he concludes that no limitation with general application can be worked into the relevant definition of 'is a part of', and consequently he feels compelled to treat mass terms in predicative position as general terms - or possibly as parts of more complex general terms. If we can assume that this procedure is intelligible, there is something gained by it, and this helps us to understand why Quine can call this the "simplest" plan. For it allows a unitary treatment of the copula; it always stands for class membership, and this helps when translating English into what Quine calls canonical notation - in effect, the first order predicate calculus.

~~In~~ In order to see clearly the various points made, and to facilitate comparisons with other proposals as well as to understand the problem of merging this proposal with transformational grammar, Quine's proposal will be presented in schematic form.

In the scheme 'N' stands for noun that can be interpreted mereologically, and 'Adj' is given the same interpretation. 'Ncount' is count noun, and similarly for 'Adj count' and N'NPcount', etc.

1) N + VP = Nmass. (if the mass term is in subject position, it is interpreted mereologically
2) ....+VP(..+N) = Ncount (with complement?). (if the mass term is in predicative position, i
is taken as a general term.)
3) Demonstr. + N = ~~Nmass.~~ count. (with the demonstrative a mass term is always taken as a general te
4) .... + VP(...+Adj) = Adjcount. (mass adjective in predicate slot is taken as general term.
5) NP(Ncount+Adj) = NPcount(Ncount + Adjcount). (if adjective modifies a count noun, then it
is treated as general term.)
6) If N + Adjcount, then N also must be count. (at least cannot be mass term.)
7) Nmass + Adj = NPmass(Nmass + Adjmass). (if an adjective modifies a mass term, it is taken
as a mass term.)
8) The copula always stands for 'is a member of the class ...'.

It follows from these rules that if an NP composed of N + Adj is in the predicate slot, then it must be interpreted as NPcount(Ncount+Adjcount).

It also follows that one does not know how to give a semantic interpretation to certain noun phrases until one sees what higher node dominates these. We shall return to this point later in our discussion.

To recapitulate Quine's reasoning underlying his interpretation of adjectives, the following three claims have to be considered. First, that the syntactic role of an expression as a noun, or adjective does not affect its referential (or denotative) role; secondly, that from the referential point of view 'red' is on par with 'iron'; and thirdly, that we need to be able to work out the semantics of complex noun phrases on the basis of the semantics of its parts.

We shall turn now to a brief summary of Parsons' proposal. Parsons construes mass terms when in subject position as singular terms naming substances. He does not think, however, that what he calls substances can be given a mereological interpretation[18]. His reason for this is that accordi to his view spatio-temporal coincidence between two substances does not guarantee identity. One of his examples in support of this thesis is that even if in the actual world all and only furnitu were composed of wood, the identity of the two substances would not follow since parts of chairs might be wood without being furniture[19]. Thus, on this view, when a mass term stands by itself in subject position it is construed as the name of a substance which is an abstract entity - thus the mass term functions in effect as an abstract singular term.

For the cases in which mass terms stand in predicative position, such as '...is gold', Parsons assigns to them aninterpretation that makes them elliptical for a complex general term. This general term is relational, and its relata are what Parsons calls "bits of matter" and substances. The relation is introduced as a primitive, under the name of "quantity of". Thus, e.g. to take Quine's example, 'the white part is sugar' becomes on Parsons' view 'the white part is a bit of matter tha is a quantity of ~~gold~~ sugar'. Bits of matter are construed as entities governed by the calculus of individuals[20]. This same interpretation is given of mass terms when they are preceded by demonstrative or quantifiers. Thus, e.g. 'some ink' becomes 'some quantity of ink', 'all rubber' becomes 'all quantities of rubber', etc. with the same structures holding as above. In this way on Parsons' analysis the copula remains always the equivalent of the sign for class membership.

In order to understand Parsons' treatment of complex mass terms, we must note that for him no adjective is a mass term; the distinction count— is applied only to nouns. As long as one acc his treatment of mass nouns in subject position, this treatment of adjectives does not result in difficulties - at least on the formal level. For the terms that the adjectives modify are not referring to mereological units, but to abstract entities. The same consideration applies to complexes when they appear in predicate position, since - as we saw - in this context the complex becomes part of a complex relational general term.

There is an additional feature of Parsons' treatment of complexes. For he is also concerned to give a semantics that will reflect certain inferences that all os us would accept as valid. Thus, e.g. the semantics should show how 'all blue water is water' comes out as a valid inference. Parsons accomplishes this by construing the inference to be about quantities - and thus, I take it and is a quantity of water, is a quantity of water'. The symbolization of this and other sentences is obvious. In the case of other types of complexes such as 'muddy water is widespread' (Parsons' example)[21] Parsons gives an analysis in terms of complex substance names and adjectives construed as regular general terms. In the case under consideration we would have the complex substance-name - if I understand Parsons correctly - 'the substance constituted by bitts of matter that are muddy and are quantities of water'.

In insisting that certain inferences that we take to be valid should also be accounted for, Parsons adds an important criterion of adequacy, in addition to the ones that Quine implicitly sets, and were presented in this paper schematically.

In order to complete this account, we must attempt a summary of Parsons' explanation of the primitive 'quantity of'. The explanation is said to be only rough and in need of qualifications.[22] We are told that to be a quantity of gold is to be a bit of matter that makes up the substance gold which is scattered around the universe. We are also told that "if it is true to say of an object (physical object) that it "is gold", then the matter making it up will be a quantity of gold". This latter account is qualified so as to rule out cases where we describe something as 'gold' only in view of its color or other perceptual quality, or something that is only partly gold, etc. and we are told that not all parts of matter that are quantities of gold are gold - a reference to the principle Quine already stated.

The following is a schematic summary of Parsons, analogous to the one constructed for Quine's proposal.

1) N + VP = Nabstr.sing. (in subject slot, N behaves as a name of a substance, not extensionally construed.)
2) ....+VP(...N) = is a quantity of N (in predicate slot, we introduce primitive 'quanity of')
3) Demonstr. + N = like 2) above.
4) No adjective is treated as a mass term.
5) identical with Quine's treatment.
6) " (except that abstract singular terms will be introduced as interpretations of Nmass where Quine would not.)
7) no analogue to Quine's needed.
8) identical with Quine's condition.
9) In order to exhibit certain inferences, reference to masses is construed as reference to quantities of substances.

We shall now consider possible criticisms of the two proposals before us. The following four points seem to me to show flaws in Parsons' account. His treatment of adjectives does not consider, and thus does not answer any of the claims and hypotheses that Quine gives in support of his interpretation of adjectives. As a result of this, as far as I can see, Parsons' account shows no difference between 'red' and 'spherical' from the semantic point of view, and does not exhibit whatever similarities there are between 'red' or 'heavy' and nouns like 'ink', or 'water.'

Secondly, his treatment of substance terms seems to leave some open ends. We saw already that substances cannot be, strictly speaking parts of each other. It seems intuitively clear to me that the substance red ink should be a part of the substance ink. In Parsons' system both substances are abstract entities, and the relation in question will have to be described by saying that all quantities of one are quantities of the other as well. Likewise, what seem like direct attributions of qualities to a substance will have to be reinterpreted by Parsons as indirect attributions. For example in saying that 'iron is heavy' I cannot attribute heaviness - on this account - to the substance itself, the substance being an abstract entity, but will have to attribute it to the quantities of the substance iron. This seems odd, at least to this reader.

What seem at least to me somewhat forced readings of certain sentences involving reference - at least on the surface - to substances, leads us to a reconsideration of Parsons' reasons for not taking substances to be mereological units. His support for this claim involved the possible situation in which two substances overlap each other spatio-temporally in the actual world and nevertheless we would not want to say that they are identical. It seems to me that instead of taking Parsons' way out, one might try the following solution. Let us consider a substance as a mereological unit - a "scattered particular" - but not only in the actual world, but also in all possible worlds. It seems to me that one could then regard as the condition of identity for two substances that they should overlap spatio-temporally not only in the actual world but also in all possible worlds. This way we could avoid the undesirable consequences that Parsons points out, and still retain the idea that has intuitive, semantic, and syntactic backing, and was first formulated by Quine and Goodman (in modern times; Aristotle had the same idea quite a bit earlier), that these mass terms denote mereological units. Of course, given this proposal, one would have even more reasons to reconsider Parsons' suggestion about adjectives, and Quine's proposal would look again more attractive.

The third and fourth difficulties in Parsons' view concern the two primitives that are invoked in his account of mass terms in predicative position. In comparison with Quine, it seems th all of the difficulties that arise in the attempt to explain how terms with mereological denotations can combine with terms that have sets as denotations, and the dual role of certain terms, are swept under the rug by the introduction of the primitive 'quantity of'. Thus whatever is gained in formal simplicity is lost in terms of explanatory power and philosophic perspicuity. Quine is driven to making use of a whole collection of predicates 'batch of furniture', 'bit of iron', etc. in view of the fact that there is no general condition in terms of which one could explain what the minimal parts of each substance-stuff are. It is not at all clear to me how we manage to bypass this problem by the introduction of the primitive 'quantity of'. Will this primitive have different senses depending on whether we talk about batches, bits, or regions?

The companion of this primitive does not seem to me any clearer, though my criticism might seem idiosyncratic. The basic weakness of the notion of 'bits of matter' seen to me questions of individuation. Of course, different philosophers might require principles of individuation of different strength. According to my view what we quantify over should be entities that can be identified across possible worlds. Given this assumption, a theory in which we quantify over bits of matter will not be attractive, since it is not at all clear how one would identify bist of matter across possible worlds.

Turning to Quine's proposal, we should note that its assessment depends not only on how well the semantics works out, but also on how it can be fitted within an adequate syntactic framework. In this connection I would like to raise what seems to me a problem. We noted that in the predicate position an adjective will be treated as a general term, and thus has a set as its range of denotation, but when it combines with a mass noun as subject, then it is treated as referring to a mereological unit. Thus, for example, in 'this ink is red', 'red' is regarded as a general term while in 'red ink is hard to read', it is regarded as referring cumulatively. But it is plausib to regard the combinations N + VP (be+Adj) and NP(N+Adj) as transformationally related. We would pr sumably derive the latter from the former (e.g. 'red ink' from 'ink is red'). If we try to combine Quine's semantic proposals with this part of transformational grammar, we arrive at the conclusion that 'red' will have one semantic interpretation in the deep structure, and another after the transformation that results in the complex noun phrase. I do not object to this consequence on the general ground that transformations should be meaning preserving and this violates that alleged principle, for I am not convinced that sufficient justifications have been given to accept that principle without qualifications. But in this type of case it does seen odd to suppose that a transformation of this kind should effect a change in semantic interpretation.

This flaw, if it is a flaw, hinges on what Quine calls the dual role of mass terms, and in this connection some doubts has to be raised concerning the intelligibility of the claim that mass terms, elliptical or not, can be treated as general terms. Quine more than any other contemporary philosopher of language always insists on the importance of distinguishing singular from general terms; partly because of the different roles that these expressions play when we assess the ontological commitment of a theory expressed by a language with these terms. The distinction is emphasized by Quine in connection with general terms and abstract singular terms; but presumably the distinctio is just as crucial in connection with non-ab stract singular terms, and mass terms are just that on Quine's account. Thus if 'red', or 'water' has two uses, as a general term and as a non-abstract singular term, then these uses are no more connected than 'redness' or 'waterhood' are connected with 'red' and 'water' respectively. Apparently it is a mere historical accident that in one case we can use different expressions and in the other we can not do that. Now Quine may be right about this, but I for one would hope that an account should be available that avoids having to postulate such strange accidents. The real problem in any case seems to be the alleged use of mass terms as general terms. If we consider paradigm cases of predicates containing general terms such as 'is a man', 'is a star', we see that these allow the intelligible formulation of expressions like 'is the same star', 'is not the same star', 'is that star', etc. with clear criteria of application. Indeed, this is the very feature of general terms that Quine emphasized in his own account. When we consider the allegedly analogous cases involving mass terms we face two alternatives. On one alternative, the analogous expressions are complexes such as 'the same bit of water', 'not the same bit of water', and in these complexes the burden of dividing reference is carried by the auxiliary expression 'is a bit of' (or 'batch', 'region' etc.). So quite apart from the question of how clear the criteria of application are for these complexes, the relevant referential functions are not carried by the mass terms. On the other interpretation terms like 'is water', 'is iron', etc. function as general term by themselves. But though we can make sense of such as expressions as 'is the same water', 'is not the same water', 'is a different iron', they do not carry the required sense. Different irons are different kinds of iron - or different golfing irons; different waters are different kinds of water, or brands of water (e.g. mineral Water, boiled water?). On either interpretation the alleged role of mass terms as general terms remains quite obscure.

Even if these qualms concerning intelligibility are not shared by the reader, we run into difficulty when we try to exhibit internal structure within Quine's interpretation. Let us consider the sentence: 'red ink is ink'. Under an adequate interpretation this should come out as a tautology. Thus, for example, whatever flaws there might be in Parsons' account, he can show this to be a tautology by interpreting it as 'every quantity of ink that is red, is a quantity of ink' ($(x)(Ix \,.\, Rx \supset Ix)$). How shall we formulate this on Quine's interpretation? 'Red ink' before the is of predication becomes a singular term, say, 'r'. 'Ink' behind the 'is' of predication becomes the general term 'is a bit of ink', say 'Ix'. So the whole sentence becomes: 'Ir' which is not a tautology. Perhaps one could reformulate the sentence in question as being about all parts (of the required sort) of the object red ink. Then the sentence becomes 'every part of the object red ink is a bit of ink'; but this again is not a tautology. Thus unless better accounts of this sentence within Quine's semantics are proposed, I conclude that Quine's semantics for mass term does not allow us to exhibit enough internal structure.

Before we turn to some constructive suggestions, let us recapitulate the conditions of adequacy for an analysis of mass terms that emerged from this paper. First, the analysis must give an interpretation to the nine schemes under which we summarized the different accounts. Secondly, the analysis should reflect and account for the deep semantic differences between mass terms and terms with divided reference; i.e. it should account for the fact that 'the same man' is well-formed, but 'the same red' is well formed only on a different type of interpsetation. (Or 'the same star', but not 'the same gold', or 'many golds' vs. 'many stars'.) Thirdly, the semantic analysis must be such that one can incorporate it into a transformational grammar. Fourthly the analysis must make it possible to account for the denotation ranges of complex expressions on the basis of the denotation ranges of simple elements. This last condition is sometimes identified with the task of giving Tarski-type truth definitions for sentences, or with the task of symbolizing the sentences to be analyzed in first-order predicate calculus, but we shall see below that such identifications need not be made.

The key to the constructive proposal to be made is the treatment of mass terms as cumulatively referring expressions both before and after the 'is' of predication. We have seen, however, that this involves treating the copula in some context as equivalent not to class-membership but to the "part of"-relation, and Quine has given some arguments against such identification. Thus any attempt of this sort must meet Quine's objections. Suppose we take the sentence 'this puddle is water' and interpret it as 'this puddle is a part of the spatio-temporally scattered individual Water'. Then we are taking the 'is' of predication to be equivalent to 'is a part of'. Quine's objection is that this equivalence will not work, because though 'x is water' entails 'x is a part of the individual Water', the entailment does not hold the other way around; not every part of water is itself water. The minimal parts that are water, however, can be specified as parts of water with certain structural properties (let us abbreviate these as SP). The same can be done for all other mass terms. To be sure, what goes into the SP-set will differ from term to term, but we still have a common scheme for the analysis of all of these expressions. Thus my proposal involves treating 'x is F' where 'F' is a mass term as equivalent to 'x is a part with the required SP of F'.

If this analysis is adequate and meets Quine's objection, then we have open to us a way of analyzing the semantics of mass terms that differs from each of the two proposals considered so far. It is now possible for us to treat 'ink' in all contexts as the name of the scattered particular that makes up ink (all the ink there is, was, or will be), and treat 'is ink' in all contexts as 'is a part (with required SP) of the individual ink'. To show how this proposal works in detail, let us compare it in terms of our schemata with the previous proposals, and let us then see how it meets the other criteria of adequacy.

1) N + VP = Nmass. (Mass term in subject position is interpreted mereologically. E.g. 'water is x liquid' is 'the spatio-temporal individual Water is x liquid')

2) ..... + VP(...+N) = Nmass (Mass term in predicate position is interpreted mereologically; e.g. 'the layer on the top is chocolate' is 'the layer on the top is a part (with SP) of the individual chocolate.)

3) Demonstr. + N = Nmass (E.g. in 'this ink', or 'this is ink', the first refers to a part of ink, the second says of something that it is a part of ink (+SP).)

4) ... + VP(...+Adj) = Adj mass. (A mass adjective in predicate slot is interpreted mereologically. E.g. 'this house is red' is 'This house is a part of the individual Red'.)

5) NP(Ncount +Adj) = NPcount. (if a count noun is modified by a mass adjective, then the whole NP is a count phrase. E.g. 'red house' has as its denotation range the class of all those houses that are also parts (with SP) of the individual

6)A) N + VP(...Adjcount) = Nmass. (E.g. 'some water is good to drink' is 'some parts of the individual Water are members of the colls of entities that are goddto drink.)

6)B) NP(N+Adjcount) = Nmass. (In a noun phrase if the adjective is count+, then so must the noun be as well.)

7) Nmass + Adj = NP(Nmass+Adjmass). (E.g. 'red ink' is a noun phrase that denotes the overlap of the parts of the individual Ink and the individual Red.)

8) The copula stands in some contexts for the 'o' of class membership and in others for the relation (part with SP) of'. (E.g. 'this is a house' and 'This is water'.)

9) Internal structure can be exhibited in the following way: e.g. 'red ink is ink' is interpreted as 'the overlap of red-parts and ink-parts is an ink-part', and this is a tautology.

It is easily seen that given this semantics the kind of difficulty involving meaning change and transformation will not arise, and that one can interpret the semantics of NP's without looking at the higher nodes that dominate them.

I hope to have shown that two of our four criteria of adequacy is met by the proposal at hand. Given 8), it is easy to see that the proposal also meets the condition that it should exhibit in some illuminating way the difference between the semantics of mass terms and count terms. According to this proposal the difference can be seen in the fact that the principles of composition for the denotation of complex mass terms differ from those of count terms. At this stage, however, we encounter a difficulty. For someone might object that the proposal meets this condition only too well. What the addition of 8) gains for the proposal in terms of showing the difference between count and mass terms, it loses from the logical point of view, since we are no longer able to express the whole semantics in terms of predicate calculus. A reply to this possibl objection leads us to the fourth condition of adequacy. For though mereological relations are distinct from set-theoretical notions, in terms of computing the denotations of complexes from the denotations of simples, the additional relations that I introduced aare just as effective as the set-theoretical ones. In terms of 'overlap', 'sum', etc. we can always show how the denotation of a complex breaks down into the denotations of simples - analogously to the way in which we can do the same in terms of notions like 'intersection', 'union', etc. Thus we have to separate the issues; if the demand is to show how the complexes are dependent on the parts, then the proposal is adequate on that account; the same is true - as far as I can see - if the demand is for an analysis that allows us to state truth-conditions for sentences or propositions. If the demand is for an analysis expressible solely in terms of the notions of the predicate calculus, then our proposal fails on that count. But I do not see why the last demand should be made; what is sacred about the predicate calculus? If the introduction of additional notions preserve effectiveness and help to illuminate the language that is the object of our analysis, why should we refrain from such introductions?

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NOTES

1) As used by Jespersen and others. See Quine, W.V.O. *Word and Object*, Wiley, New York, 1960, p.91.

2) Chomsky, Noam, *Aspects of the Theory of Syntax*, MIT Press, Cambridge 1965, pp.82 ff.

3) Parsons, T., *An Analysis of Mass Terms and Amount Terms*, mimeographed

4) Quine, *Op.cit.* pp. 90-91.

5) *Ibid.* p.96.

6) Moravcsik, J.M.E.,"Subcategorization and Abstract Terms"*Foundation of Language* Dec. 1970.

7) Leech, G.N. *Towards a Semantic Description of English* Indiana U.P. Bloomington 1969, pp. 134 ff

8) Quine, *Op.Cit.* pp. 91-92.

9) Cartwright, H.M. "Quantities" *Philosophical Review* 1970 79:25-42.

10) Parsons, *Op.cit.* pp. 1-2.

11) Quine, *Op.cit.* p.95.

12) Goodman, Nelson, *The Structure of Appearance* Harvard U.P. Cambridge1951, pp. 42 ff.

13) Quine, *Op.cit.* p.97.

14) *Ibid.* pp. 97-98.

15) *Ibid.* p.101.

16) *Ibid.* p.104.

17) *Ibid.* p.99.

18) Parsons, *Op.cit.* pp. 8 ff. and pp.28 ff.

19) *Ibid.* p.30.

20) *Ibid.* p.13.

21) *Ibid.* p.23.

22) *Ibid.* pp. 11 ff.

THE CONCEPT OF UNIT IN CHILD GRAMMAR

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1. Introduction. Several aspects of the study of language acquisition are very intriguing for their potential application to other studies. As language acquisition is one of the very few primary, non-mediated forms of human learning, it should contribute significantly to the psychological study of learning. As it is also one of the few bodies of data on the English language from non-literate informants, it cannot be ignored in the formulation of linguistic theories. This paper discusses a new approach to the study of language acquisition data and draws some conclusions relevant to the fields of learning and linguistics.

Linguistic science has always dealt with units in the investigation of language structure: phonemes, distinctive features, words, sentences, to name a few. Such units are static entities used to describe (systematically and economically) the language of adult speakers. The economy of a child's linguistic system is of a different nature from that of the adult system - it must be economical not only from the point of view of a speaker but also from that of a learner (possibly opposing points of view) - and is thus subject to different constraints entirely. The child's linguistic system is also not static, but instead is very dynamic. Thus we must remain open to the possibility that units different from those of the adult grammar may be necessary in the description of child grammar. Such units ideally are revealed by the data itself and their utilization in a linguistic description should enable us to see more clearly the actual processes by which language is learned.

Most child language studies of the last several years have utilized the framework and the methodology of generative grammar to trace the expanding language of the child. Although the framework here is quite different, it is not in opposition: different approaches to data always reveal different aspects of their potential. This approach is complementary to others and is worth pursuing for the unique conclusions it offers.

A 'unit' is the smallest section of the speech chain which the child uses distinctively. It is not defined by the investigator's recognition of distinction, but rather by the child's evidencing in some significant way that he has achieved an ability to organize his grammar on the basis of that unit. The foregoing is not meant as a definition, but does serve to limit the definition of 'unit' which we probably all share. In the course of the discussion of phonology acquisition, the concept of unit will be used extensively and its delimitation should be clear. Subsequently the applicability of the concept of unit to syntax and semantics will be discussed.

George Miller's study, "The magical number seven plus or minus two" is very relevant to the concept of unit. Miller's paper deals principally with the idea that adults can encode larger amounts of information when they chunk information into larger blocks since short-term memory will handle approximately seven blocks. Increased memory capacity thus depends on the ability to augment the size of a block rather than expand the number of blocks to be handled. The theory of language acquisition presented here depends on an across-time process which is essentially the same as the one that Miller describes. As the child's sophistication increases, he is able to chunk more information into a block of speech. The way the child accomplishes this goal is by decreasing the size of the units of his speech, while often retaining and sometimes even increasing the time-length of utterances as they occurred when the previous unit was employed as the basis of system organization. Thus while the child is maturing toward the goal of seven blocks of information in his speech he is simultaneously developing his ability to chunk more information into each block[1].

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[1] To illustrate this point, let us look at a few sample negative sentences from Erica's speech. At age 2.0 she uses few negatives, all of the form
"No.'
or
Won't
Don't Verb.
Examples of the second are 'Don't do that' and 'Don't know.' 'Do that' seems to be one word for Erica at this time and always occurs without a pause in the acoustic signal. The most sophisticated form of negative sentence then at this stage consists of a negative unit plus a verbal unit. Six months later Erica uses more complex negative sentences, such as
'He doesn't like egg.'
'I don't want to touch off sparklings.'
'He's not jumping over.'
'I'm not gonna eat some egg.'
'Don't fit Stephanie.'

The structure of her negative sentences at this point can be described as

Pro Neg Verbal

where Pro is optional, Neg can be 'don't', 'doesn't', or 'not', and Verbal is an expanded form of the unit Verb of six months earlier. Whereas before her negative sentences consisted of two units, here they consist of three. While only one unit (a single word) could fit into the Verb slot earlier, several words can fit into the Verbal slot, and that can be viewed as a larger amount of information chunked into one block, a block which happens to have been a unit at an earlier time. At 2.9 Erica uses sentences like

'That bee must not do that.'
'No, piggy, you better not hit people.'
'He is not doing it.'

which suggest that she is expanding the negative unit into two units which encompass an auxiliary verb and a negative which are chunked together into one block.

2. Outline of phonology acquisition. Roman Jakobson, in his extremely important work, Child Language, Aphasia, and Phonological Universals, made four important points which have been summarized by Charles A. Ferguson as follows:

> 1. At any given synchronic stage during the process of language acquisition, the child's speech has a structure of its own.
>
> 2. In addition to this central, systematic, structural core of speech there are some marginal (extra-systematic) elements.
>
> 3. At any given stage, the child's speech will exhibit systematic correspondances to the adult model.
>
> 4. Across all children and all languages, there is a regular order in the acquisition of phonological distinctions.

These four points must form the basis of any theory of phonology acquisition. Jakobson's work is devoted largely to an exposition of the fourth point: many diary studies have indicated the accuracy of the third. Most of section 2 of this paper is devoted to a description of the structure mentioned in point 1. At the end of the section the second point, which has until now been largely overlooked, is discussed: it is an extremely important aspect of the study of language acquisition.

Much of the earlier literature makes a distinction between a 'pre-linguistic stage' and a 'linguistic stage', the separation occuring at the point when the child acquires his first word. The evidence for that acquisition may be either the production of that first word, or the contrastive production of the first two words. This distinction between two stages is arbitrarily based on the criterion of the adult's recognition of an overt manifestation which happens to be explainable in terms of adult speech, and is thus not only not necessarily justifiable in terms of the child's linguistic capacity at any one point but also may be extremely misleading, in that it implies that this is the one major step a makes in linguistic knowledge. The theory presented here assumes that there are a large number of interrelated stages, representing various degrees of sophistication, which cannot be strictly isolated from one another in any such neat manner. It also assumes that the child, from fairly soon after birth, begins his linguistic development, and therefore manifests no pre-linguistic stage as such. The pre-verbal stage is very short, and is followed by babbling, the significance of which has just been guessed at prior to this time.

The babbling period begins with the production of short utterances and progresses eventually to include production of quite long utterances which can be characterized as sounding subjectively very much more language-like than their precedessors. Early in this period the child is aware of the difference between human and non-human sounds in his enviroment, an innate endowment: during the babbling stage he in addition develops a linguistic identity of his own, i.e., the closer he can match his sound productions to his perceptions of human sound, the more he can identify himself as a member of the species community. He is surrounded, moreover, by an incredible diversity of sound, for he is able to hear phonetic distinctions with great accuracy (although there is no reason to assume consistency) but he has no concept of the potentiality of a system underlying that array of sounds -- the system is deduction he will make much later on the basis of his own speech behavior. Therefore those perceptions which his production is compelled to match are pretty random.

The first of the child's endeavors which we notice is the increase in the length of the strings he produces: together with this is an increase in the total amount of verbal output per time segment. The increase in output is probably in part a maturational result and in part a behavioral evidence of the child's increasing awareness that the speech of the adults in his environment consists of longish but finite strings of random sound: the child's earlier short utterances have given him the practice necessary for these longer outputs, which are more rewarding precisely because they more closely approximate what he hears as language, namely long random strings. In other words, within the child's world, he is beginning to satisfactorily participate in the process of linguistic exchange known as communication. This constitutes a first major step in socialization (or the learning of semantics) by its suggestion of a unit which can carry meaning, namely a long finite string of sound separated by pauses, known as 'sentence'. In fact the sentence in this way becomes the first linguistic unit for the child.

A significant thing which is occurring during this time is the initiation of a process which is described in detail by Braine in "On two types of models of the internalization of grammars". Briefly summarized, this process involves the operation of a series of storage devices within the brain. These storage devices, or black boxes, are ordered with respect to the stregth of the learning they represent. All linguistic data enters the first black box, and all data which cannot be shifted fairly soon to the next box is eliminated from the first box by forgetting; data shifted to the second box last a little longer before they must be shifted to the third box -- where they will last even longer -- or else returned to the first box where they are subject to the same time restrictions as any new data entering that box. In very simplified terms, data are shifted to a higher box when enough instances of a paricular type of data are collected in a particular box to warrant such a shift; they are shifted to a lower box if additional occurences are not found. This model is proposed by Braine to account for grammar learning, but it works just as well for the sound system. The process requires no negative feedback whatsoever (and indeed there is strong evidence that negative feedback about either pronunciation or syntax is not utilized by the child.) It provides us with a picture whose implication is that that which occurs most generally in the input will be sorted out first by the child and will therefore occur first in the output; that which is more limited in detail which the child can afford to turn his attention to when he has mastered the control of the more general aspests of grammar or phonology.

The manner in which this process works during the late babbling stage is quite simple. The child is still listening to a vast amount of phonetic input which sounds reasonably random. But the grossest features of the input -- namely the supersegmental features which we call intonation -- move rapidly from box to box and are learned before any other aspects of the sound system. In conjunction with the increasing length of his babbling utterances, we would expect the child to make use of this new knowledge of intonational structure by imposing a small number of recognized patterns on his babbling utterances to make them sound once more like his perceptions of the utterances of adults -- longish strings of random sounds with superimposed intonational structure. There is some evidence that children do exhibit intonation patterns characteristic of the adult language in their late babbling, although the evidence is certainly inconclusive as yet and the matter needs more investigation[2].

The preoccupation with intonation which the child exhibits in his late babbling stage has distinct ramifications in the subsequent step in phonology acquisition. Before we can examine this we must backtrack slightly to examine two concepts which the child has developed. The first is the concept of unit, which has so far had its only manifestation (in production) as the sentence-unit. The only relevant phonetic feature of the sentence-unit is the intonation which it carries. We may therefore suspect that when the child begins to look for a unit smaller that the sentence, he will be predisposed toward finding one which is still a carrier of intonation. The second concept as yet exists only in the child's preception; his overt behavioral evidence of this concept is purely non-linguisitc. Specifically, he is able to recognize the name of a game (such as 'patty-cake') or other similar label which obviously elicits from him a fixed behavior pattern. He may not be reacting to the exact words in toto which the adults use to label the game, but he can recognize some part of it (as was true of the child who produced the correct behavioral response which was expected for 'clap hands' when he recognized the word 'hands' embedded in his father's sentence, a sentence addressed to another adult and dealing with a different topic.) Labelled games of this type apparently exist in a large variety of cultures and are usually aimed at the 'pre-verbal' child. When the child is able to react consistently to such a stimulus, we may conclude that he has learned that a particular subsequence of the sentence-unit may have meaning by itself and, in particular, that a linguisitic string may have 'meaning'. Whether this represents the acquisition of the concept of 'word' is actually still an open question; certainly this is at least a precursor of that concept, but the amount of generalization necessary from this pattern to the concept of 'word' is significant, and may still be in the future. Unquestionably, however, this step represents the child's new awareness that some of the vast number of phonetic differences in the sounds around him are inconsequential. His tolerance of the small differences in subsequent adult productions of that label indicates that he has made the first giant step in the acquisition of phonetics -- the realization that some but not all sound differences are inconsequential, and particularly that certain slight phonetic variations are 'free'. It is probably often true that a game name or other such label will typically be offered to the child in a higher-than-normal pitch or with an exclamation intonation, thus making the child's job of recognition somewhat easier than it might otherwise be. In addition, acquisition is facilitated by the many reproductions of the word or phrase, often in isolation, and by the fact that it is one of the few bits of linguistic input which is directed at the child in particular.

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[2] A study of the intonation of infants in English-, Russian-, and Chinese-speaking homes is being conducted now.

As we have said, this focus on intonation has important ramifications. Again following Braine's model, we see that once the child has mastered some of the salient aspects of intonation he is free to turn his attention to the phonetic qualities of sentences once again. In grammar acquisition, we see that after the child has gone through a stage of holophrastic sentences, he deduces from the model a particular type of two-word relationship, ignoring all other aspects of word combination. Similarly, during sound acquisition, the child who has operated with a sentence-unit for a while is ready to abstract out of the model a more salient unit: his experience has taught him that a limited number of contrasting sentence-intonations do not suffice to express all possible meanings that this verbal environment seems to offer, and so he knows that he still has a job to do, although he is not aware of the incredible magnitude of the job. There are two significant factors which determine the precise nature of the next linguistic concepts he will master:

(1) he still can hear a huge variety of phonetic differences, and he has no possible way of sorting out from this mass which differences are inconsequential -- indeed he does not yet realize in any pervasive way that most of the differences are inconsequential (and

certainly has no suspicion of the variety of ways in which a difference may be inconsequential) -- and he has no semantic or syntactic clues which will aid him in developing a relevant discovery procedure; and (2) he has previously worked with only one type of unit, and that unit has signficantly been one which carries intonation. Thus his search for a smaller unit than the sentence is, in effect, a narrowing-down process which can carry intonation; there is absolutely no reason to suspect that the child would be able to achieve the understanding of a unit as small as the segment, and all of the evidence presented so far indicates that this next significant unit is the syllable.

Once this notion of the syllable has been arrived at, further babbling may or may not continue; if it does continue, its function is not entirely clear -- it may just be a remnant of 'fun' vocal activity; if it does not continue, it may be that the child has realized the magnitude (partially) of the job before him, and he is embarking on the activity of devoting much of his attention to the solution.

The initial syllables are all CV types[3]; this phenomenon, together with the facts that almost all languages have CV syllables, and that CV syllables are statistically the most prevalent among the different syllables of a given language, are all due to the same cause: that they are phonetically simplicity[4]. (Since we have no evaluative way of defining 'phonetic simplicity' in linguistics, we have avoided using the notion for a long time now, which has actually been a good step in the direction of not over-using and mis-using the notion. We see in child language data, however, a good criterion for defining this notion: however, we again must not over-use the argument, because the facts of phonetic simplicity are interfered with by the concurrent phonological learning.)

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[3] A detailed discussion of the acquisition of syllable structure is given in "The Acquisition of Phonology" LBL Working Paper No. 34

The phonetic realizations of these first syllables may be extremely varied, except that they all have features of stress and/or pitch. At about this same time, with the help of both his new-found short unit and labelling activity of the adults around him , but also with the aid of other devices which we know nothing about, the child develops the semantic notion of the 'word,' a linguistic concept of great consequence.

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[4] Jakobson ("Why Mama and Papa") speaks of this tendency: "During the babbling period in the infant's development, many of the uttered syllables consist of a vocalic sound succeeded by a consonantal articulation. The most natural order of sound production is an opening of the mouth followed by its closure....As soon as the child moves from his babbling activities to the first acquisition of conventional speech, he at once clings to the model 'consonant plus vowel'. The sounds assume a phonemic value and thus need to be correctly identified by the listener, and since the best graspable clue in discerning consonants is their transition to the following vowels, the sequence 'consonant plus vowel' proves to be the optimal sequence..."

The word and the unit become equated, and the child's perception of the minor phonetic variations of the words of his environment leads him to the conclusion that a certain amount of phonetic variation is permissible within the definition of a word (syllable) which still retains its identity as opposed to all of the other words of his vocabulary. He may ascribe too much leeway to this phonetic variation, and will have to correct that later through counternotions of phonetic invariance.

In his early inventory of syllables (which constitutes both the syllabary -- the phonological inventory -- and the lexicon -- the vocabulary inventory) the child will of necessity utilize some distinctions to keep these words apart. They are not always successful distinctions, and the result is that it is often difficult for adults to tell when the 'first words' have been introduced into the child's language. If they are successful, and the child will soon find a way of making them so, they may depend on distinct intonations[5] or may depend on the embodiment of a phonetic distinction which happens to be incorporated phonemically into the adult language, such as pa vs. ka. This second type of distinction will eventually be added, if not immediately, and it is this which is most interesting for our purpose. The child's strategy is quite simply to select and use a variety of different syllables, the repetitions of which enable the practice of two necessary types of learning: by practicing different syllables, the child begins to grasp the notion of phonetic contrast, and, particularly, consistent contrast: by practicing different repetitions of the same syllable at different times, the child begins to grasp the notion of phonetic similarity and identity, together with the limits of the absolute free variation which is an inherent part of any phonetic series of like phonetic manifestations. Through the necessary processes which result from the syllable's place as the elementary unit of speech, the child develops notions of rules in phonology, directionality of rules, and elementary phonotactics.

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[5] For example, Leopold reports that Hildegards's first distinction was that of ʔə́ with ʔə̂.

Through his practice of syllables, the child develops the specific motor-coordinations and brain directions to the muscles which will be an unconscious part of his language-use for the rest of his life. Through this process he suppresses all those extremely similar but not exactly the same possible sets of neural commands which would produce slightly different acoustic results, and this may be the reason why correct pronunciation in second language learning is so difficult: in fact, it predicts that such learning will be more difficult if it involves neural command patterns which had to be explicitly suppressed, as opposed to those which were irrelevant and therefore neither practiced nor necessarily suppressed. To give a concrete example, suppose that the child incorporates into his syllabary *ki* and *ki*. Let us look closely at what the child both learns and suppresses in the process.

First he learns the correct front vs. back productions of /k/ not as allophonic variants of the same phoneme, but as the distinctly different onsets which these two phones represent before the two different vowels; it will not be until much later that he 'realizes' that these two different k 's are variants of the same phoneme, a fact which will come considerably after the understanding of 'complementary distribution'. For now, he is simply learning a set of neural commands which determines the salient features of an entire syllable *ka* and an entire syllable *ki*, including the specific changes in formants which determine the connections between *k* and *a*, between *k* and *i*, as well as the targets for formants at the onset of the syllable and at its end (the latter also including a portion of time before the end) and as well as the time relationships which connect these targets in an acceptable pattern. In the process he learns the amount of variation which may be tolerated for the result to be a correct production, and must suppress those configurations which result in productions which are just beyond the limits. He need not suppress those possibilities which are sufficiently beyond the limits to be excluded automatically once the limiting possibilities have been excluded. In addition, he must learn to produce these syllables with aspiration on the initial part, or onset; he learns to produce the 'correct' amount of aspiration by suppressing the slightly different possibilities of too much or too little aspiration, but he does not have to suppress the extremely different possibilities of lack of aspiration or extreme plosion. It is later, when he must learn to control both the unaspirated k 's of other syllable positions and the unreleased k 's of still others, that he will have to suppress those as possibilities for the allophones of /k/ which occur in the environment $\underline{V}$. We would suspect that since he does not ever have to suppress extreme release, he would be able to learn a distinction of $/k_1/$ with the degree of aspiration acceptable in English vs. $/k_2/$ with an extreme explosion with reasonable ease in a foreign language. The presentation of this paragraph is, of course, over-simplified, omitting both detail of the processes mentioned and also additional processes involved in the same picture, but the idea is a significant one: the child learns the constraints of phonetic representation automatically as part of the precice of the syllable acquisiton stage, and long before those constraints play any part in the phonological aspect of language. Thus we can conclude that these phonetic details rightly do not belong to the structure of language in any way, and allophonic statements have no place in a linguistic description of phonology.

In relation to the concept of unit, it is important to notice that, although the syllable will be replaced by more sophisticated units as the basis of phonology, the fact that is was at one time the basic unit of phonological organization leaves its imprint forever on the adult system. The neural encodings which are developed at this early stage impose the articulatory restraints, which cannot be accounted for in any other systematic way.

Inherent in the syllabic function of sound learning are the two opposing and complementary processes of 'grouping' several phonetically similar manifestations into one unit (i.e., building up units by means of losing distinctions) and of 'degrouping' (i.e., extracting out from a vast number of different sounds some distinctions which 'work'). These learned distinctions,we must remember, are at the level of the syllable, the only significant unit the child has so far. All such distinctions, throughout the entire process of acquisition of sound system, will continue to be learned at the level of the syllable. Once the child has begun the process of deducing segments and distinctive features from their syllable context, that process will slowly transfer the function of phonological elementary unit from the syllable to the segment and/or distinctive feature. As the transfer process becomes more rapid, and its results therefore more pervasive, information about distinctions, acquired at the syllable level, is rapidly subject to the transfer process.

We can now view the child who has a reasonably large syllabary and has begun the deductive process of judging some small phonetic differences to be non-distinctive and certain other gross phonetic differences to be distinctive, and can view him in the light of the acquisition model which we have proposed. As he sorts this data of his syllabary through the black boxes of memory, he slowly but surely discovers the significant generalization of the processes of judgment of phonetic sameness and phonetic difference, that generalization being that the judgment need not be confined to individual syllables. Although on the level of neural and motor control, and thereby production, the exact phonetic qualities of segments are still controlled by earlier syllable learning, on the level of segmental encoding the differences between the several different t's before distinct vowels become insignificant. The child 'realizes' that these are in some sense the same t (because the transfer of the more miniscule phonetic differences to higher boxes has left the lower ones free to deal with these larger differences), and thus the concept of a phonological unit smaller that the syllable is discovered.

At the very beginning of this process, just one or a very few segments are thusly extracted from the data of the syllabary. But there is a chain-reaction through the syllabary which insures that eventually all (or almost all) of it will be reanalyzed this way. Suppose, for example, that consonant X is first discovered as a segment in this manner; that implies that there are in the syllabary several syllables in which consonant X occurs, and the new status of consonant X leaves all of these syllables in an unusual position, partially devoid of their earlier integrity. The vowels A, B, C,.....of these syllables which involve X as onset will then be *subject* to immediate reanalysis as segments, too. Those which occur with reasonable frequency in the syllabary will in turn *realize* this potential reanalysis (while a few may not) and will therefore instigate reanalysis of other consonants, Y, Z,....with which they occur in syllables. Through this process, then, a large number of segments will eventually be developed as independent units of the phonology.

(It is important to interpose here a brief explanation of the precise meaning of 'segment' in this context. The notion is only vaguely similar to the idea of the taxonomic 'phoneme'. The segment is limited to only one possible position with respect to other consonant or vowel segments and word (syllable) boundaries. In the above example, consonant X is limited to the environment _V. In other words, the segment is limited to the environment from which it is extracted. In addition, the segment does not necessarily include all of the reflexes of a particular 'phoneme' -- the child might, for example, have two different *k* segments, for obvious reasons.)

It is now apparent that a child will have a larger repertoire of distinctions among consonants in word-initial position then in word-final position throughout most of the acquisition period precisely because segments first are discovered through their occurrences in CV syllables, and later in CVC syllables -- the chain reaction takes much longer to affect final segments.

The order in which individual segments are acquired varies greatly from child to child. The order in which distinctive features are acquired, however, is regular, as has already been pointed out by Jakobson; and the expected regularities are precisely those which Jakobson has described as general properties of the nature of language.

Soon after the child begins extracting segments from his syllables, he is in a position to compare these segments and derive from them a still more elementary unit. This unit is the distinctive feature, and its earliest occurrences will be of a general nature, e.g., consonantal vs. vocalic. Later, refinements such as the division of one feature into two -- consonantal vs. non-consonantal and vocalic vs. non-vocalic -- will take place. As these features represent the ultimate units for which the child has been searching, no further learning beyond the refinement of this system itself (except for the insignificant further generalization of segments previously discussed) is predicated upon it.

One further generalization will eventually occur in this process of extending notions of phonetic sameness and phonetic difference. This last step requires even greater tolerance for phonetic diversity than the previous one, and it is reserved probably for a much later stage since it is not a necessary step in the sense that it is not prerequisite for the development of a linguistic concept, nor is it an ordinary step in the series of reanalysis that the child experiences. In fact, it is nothing more than a logical *conclusion* to the distinctive feature acquisition process which is bound up with the segmental recoding This generalization is that which identifies some segments as being 'same' and lumps them together, resulting in a limited inventory of segments which is close to the inventory of the systematic phonetic level as proposed by Chomsky and Halle. By means of this generalization, the child is able to lump together the contextually-conditioned variants of a segment, such as *t*-/ _V, -*t*-/V_V, -*t*/V_ , and the several segments *t* which occur in various positions in various clusters. In addition the child is now able to, if he has not already done so, group together 'allophones' which are conditioned by specific and more limited qualities of the context -- an example being *k* before front vowels, and *k* before back vowels.

The child's attention is now focused on discovering the complete system upon which is based the structure of phonology. Schvachkin's experiment with Russian children indicates that there is evidence in perception that this ordering is both neat and explicit. Evidence in production is not nearly so neat, indicating interference from phonetics and possibly also from that property of language which we designate by the term 'marking'.

The interference of phonetics is a two-fold one, and is deeply embedded in the pervasive conflict between phonetics and phonology which the child has spent so much effort resolving. At early stages, phonetic ability is considerably greater than can be displayed through the structural seive of phonology -- thus we can often find that the child's very first production of a particular word is phonetically quite accurate, while subsequent productions are mediated by the existent phonology and seem therefore to be phonetically much less sophisticated. (This fact, incidentally, indicates that all child sound system data which have been collected in 'imitation' situations are probably unreliable and even misleading.) At later stages -- when phonetic suppressions may have been falsely overgeneralized, when phonetically 'difficult' segments such as θ are being encountered, or when segments are sufficiently infrequent to make the appropriate feature generalizations less than obvious -- interference from phonetics has precisely the opposite effect: namely, certain phonological distinctions which have been acquired may be inobvious with respect to certain segments because there is no phonetic distinction by means of which the child is able to show us that he does in fact control the relevant phonological distinction. A very good example of this situation is the status of the fricative consonants in the speech of two of the children discussed in the paper "The Two-Year-Old Stage....".

Mackie and Erica had acquired all of the relevant features for the complete set of English fricatives, as evidenced by the operation of those features in other parts of their systems. Their treatment of those fricatives which they partially or completely lacked (phonetically), in terms of the patterns of substitutions and omissions which we observe for those segments, indicates that their phonological systems have 'slots' reserved for these segments. To give one example, Erica correctly pronounces [ð] when it occurs in an extremely limited environment -- immediately after a segment marked +[nasal]: in all other environments, [ð] is either omitted entirely or [d] substitutes for it -- these two possibilities each occurring approximately 50% of the time. As this pattern is quite different from that of any of her other segments, we can conclude that she has acquired a /ð/ which is distinctive from other segments; phonetic interference prevents the consistent phonological evidence of her learning. In the limiting case, we can imagine a situation in which a relevant piece of phonological learning is completely obscured in production data by even more subxtantial phonetic interference.

The data on acquisiton of fricatives present in the corpora from Erica and Mackie, together with data from a half dozen other children at various ages, indicates that of the four pairs f:v, s:z, š:ž, and θ:ð, the voiceless consonant is acquired before the corresponding voiced on each of the first three pairs, while ð is acquired before θ. In addition, the evidence we have for these four pairs indicates that the second member is acquired quite differently for each. The entire matter of marking has not been investigated sufficiently for a conclusion any stronger than: markedness may be a factor of this strange situation. Markedness is even more obviously involved in phonology learning when we realize that some features are quite skewed in terms of the child's control of them, as specifically exemplified in the child's considerably later control of [+cont] than [-cont]. The theory of marking may, in fact, benefit considerably from the evidence offered by sound acquisition data, and vice-versa.

The theory as outlined so far indicates a path from babbling to a stage where phonological organization involves segments roughly of the systematic phonetic level and which can be designated at least in part by distinctive features. It remains to be shown how the systematic phonemic level is reached from this stage. Data relevant to this last step is not really to be found in free-speech data of pre-school children and I intend in the future to carry out controlled experiments with children ages 4 to 10. A detailed study of the processes in the syllable stage provides evidence for the child's developing the concept of rule directly from the data he has; evidence from the systematic phonetic stage (see "The Two-Year-Old Stage...") indicates that children experiment with a variety of rules in their efforts to find correct, usable ones. On the evidence of Leila Gleitman's study of noun-compounding in English, we may assume that some but not all speakers of English learn a complete set of systematic phonological rules, and the majority learn those rules to some degree.

One of the most interesting (and unique) predictions of this theory is that of idiomaticity. Several types of idioms arise during the acquisition process, some of them temporary and others permanent.

(1) The most short-lived idioms are the phonetic idioms which arise during the early syllabic stage. Frequently a child will pronounce a word with great accuracy on his first attempt, and subsequently reduce it to a CV syllable which complies with the constraints of his system.

(2) Phonetic idioms also arise, early in the acquisition process, which retain their idiomatic form for a long period. Preliminary evidence suggests that these idioms may be semantically favored, but exactly why they exist is still unknown. They are 'memorized' as entities and much later are brought back into the constraints of the system -- i.e., are later analyzed. Considerably more

common than has been suspected, these idioms are frequently overlooked because either (a) they can be analyzed as a part of the system without modifying the system at all or (b) they are of sufficiently small deviation from the system that they can be accounted for by slight modifications incorporated into the system. (Notice that the second alternative in practice means that the investigation, by not being able to identify the idioms, has done some injustice to the child's system in his description of it.)

A clear example of this type of idiom comes from Leopold's data for his daughter Hildegard. At 0.9 she began using [prəti], a word which remained one of her favorites for a long time. Her system at that time included only simple CV syllables and reduplicated CVCV words. At 1.1 and 1.3 her system expanded to include complex CV syllables (at 1.1 she began to use partial reduplications and at 1.9 [prəti] changed to [pɪti], her first word combining four different segments. Other four-segment words soon followed, indicating that the simplification of 'pretty' was actually a reanalysis of a phonetic idiom to allow it for the first time to comply with her phonological system.

(3) The two idiom types described above are progressive idioms. More interesting are the regressive idioms, those which account for elements of language which do not 'catch up' with the rest of the system -- i.e., which remain encoded in a form which utilizes a unit of an

earlier stage than that utilized by the remainder of the utterances.

At the point when the child begins to use a new unit, the vast majority of his utterances will then be idioms until they are reanalyzed into the new framework. (For example, the child who continues to babble after using a few syllabic words with reasonably consistent meaning can be viewed as having a repertoire of idioms in the sentence unit.) More interesting are those few idioms which remain unreanalyzed when everything else has been incorporated into the new system. Some of these may never be reanalyzed and thus remain as phonological idioms in the adult system, pieces of data which cannot and should not be analyzed in the same manner as the rest of the data.

There are two types of phonological idioms, those which are culturally shared and those which are idiosymoratic. Examples of the first are syllabic idioms such as [ʔəʔ-ʔəʔ] and [m:ʔm:], 'no' and 'yes', which are learned early by chidren and not reanalyzed. The stylized hissing noise of a teakettle and other sounds produced by protracked fricatives come under this category too. Idiosyncratic idioms are less easy to cite for obvious reasons. In my own speech I find imitations of animal noises (which differ from phonemicized versions like 'bow-wow'), a variety of isolated foreign-language words, and some baby-talk items (which can be used only with a unique pitch pattern) as some examples: doubtless there are many more, some of which will be very difficult to discover because of their seeming compliance with the rules of my system. For those people who learn a second dialect well, the few revealing words which show distinct signs of the first dialect probably come under this category also.

The concept of unit, which is very powerful in phonology, can be extended to discussions of syntax and semantics. It has not been persued in as great detail,there, but its usefullness has only begun to be explored.

3. Applications to grammatical analysis. The expansion of the number of chunks of information in a child's utterances is due in part to maturational processes and in part to his expanding ability to encode more information in a given chunk.

The earliest stage of syntactic development is that of holophrastic sentences, when the child utilizes a single syllable as the basic unit on all levels and equates it as a sound, a syllable, a phrase, a sentence, and an idea. Just as the child learns to put together two syllables to form a larger word, he puts together two words to form a larger sentence. The step which the child takes when he begins to use two-word sentences is one of the most crucial he will have to make during the entire process of syntax acquisition. It is the first time that he has concatenated two chunks of information, i.e., utilized a syntactic function. (It is significant that no children have been reported to go through a 'three-word' stage: the essence of the two-word stage is the concatenation format it offers.) After this stage is over, we find that some of the concatenations which have been developed will serve as a basis for chunking; e.g., if the child uses a sentence A+B during the two-word stage, he may use X+(A+B) later. An alternative method for lengthening sentences is to expand one of the elements; e.g. to use (A+X)+B or (X+A)+B, etc. In this way he can build up sentence length without any longer limiting himself to a specific length as an upper limit for all sentences.

At age 2.0 the majority of Erica's utterances were still one- or two-word sentences. A few sentences were longer. Those which were answers to questions were among the longest samples because they utilized repetitions from the questions. We might suppose then that a sequence repeated from a question constitutes no more than one unit. The two-word sentences cannot be described by a pivot grammar: Erica has a very large vocabulary, talks a lot, and has incorporated into her sentences a large variety of syntactic combinations. For example:

'Fall down.'
'On knee.'
'My frog.'
'Eye big.'
'Put on.'
'Got eyes.'
'There eyes.'
'Shoes off.'
'I'm finish.'
'The leaf.'
'Whole banana.'
'See grandma.'
'Fly allgone.'
'Need help.'
'Erica's stockings.'
'Going night-night.'

In other words, despite the apparent short length of most of her sentences, a fairly simple grammar could not account for Erica's speech at this time. Although we will not present a complete grammar for Erica at this stage, the following guidelines would be used as constraints on such a grammar:

(1) Most of the rules of this grammar describe the internal structure of the unit, the two-word sequence. For example,

$$U \rightarrow V + N_{obj}$$

which accounts for such sentences as 'Got eyes.', 'See grandma.', and 'Need help.'. A rule of this type is expected to later expand to permit other two-word sequences to occur in either the V or N_{obj} positions.

(2) A few of the two-word sequences can still be accounted for a single unit , along with all other one-word utterances. 'Fall down.', for example, also occurs in the two-word sentence, 'I fall down.'. Neither 'fall' nor 'down' occurs without the other. Later we would expect one of these words to begin combining with still other words; when the second does so also there is absolute evidence that they are distinct items, although even then in the sequence 'fall down' they may still constitute an idiom.

(3) Some two-word sequences may not be describable by a rule such as proposes under (1) because they are semantically unique -- a general rule would in fact account for only one utterance. 'On knee.', for example, is obviously the prototype for a large number of two-word sequences which will appear later, but it is now the only such phrase. By accounting for it as a progressive idiom, we also prepare in the grammar the path of development we expect to account for in the future.

(4) One-word sentences can be considered as idioms (regressive) and do not have to be accounted for by the grammar per se as long as the grammar is considered to be a reflection of the child's current linguistic knowledge rather than a description of all utterances.

(5) Longer sentences, which seem to call for complex grammatical description, can be handled as progressive

idioms, in part, and can largely be explained as extensions of Erica's two-word combinations. Some examples are

'I don't want want the clothes on.'
'Come see choo choo train.'
'Watch him, let's watch.'
'I catch a fly.'
'He going home for breakfast.'

The first example is particularly interesting in light of Dan Slobin's experimental data, which indicate that when asked to repeat sentences children delete unnecessary word repetitions which occurred in sample sentences. The voluntary inclusion of such a repetition here seems to indicate that the sentence 'I don't want the clothes on' would be too much for Erica to handle grammatically; the two shorter utterances 'I don't want' and 'want the clothes on' are more reasonable in terms of her current grammatical ability and they can be concatenated together as if each were a unit. Neither of the two shorter sentences could be used alone without the word 'want': therefore each must include it. 'I don't want' follows the pattern of Erica's other negative sentences, where 'don't' plus verb seems to act as a single unit, a negative verb. 'Want the clothes on' is a response to the mother's prior question 'Do you want to put the clothes on?', an idiom of immediate repetition. In the second example, 'Come see' functions as a single word. The third sentence is an even clearer example of the explanation given above for the first sentence. The fourth is probably representative of the extreme limits of the capacity of Erica's grammar at this time. The firth is unusual and difficult to explain. Its occurrence was preceded by 'He going home.' but the entire sentence is reasonably thought of as a progressive idiom, particularly since 'for breakfast' is unique, Both semantically and syntactically, in the corpus.

When Erica was 2.6 we began a 20-hour tape series which covered a short period of time, providing us with a large corpus for a fairly uniform period. At this time Erica's grammar was considerably more complex than six months earlier.

Mother:	What do you want for lunch?
Erica :	Peanut butter and jelly.
Mother:	What do you want to drink?
Erica :	I want to drink peanut butter.
Mother:	You want to drink peanut butter?
Erica :	No.
Mother:	That's pretty silly, isn't it?
Erica :	Uh huh. I'm gonna eat orange juice.
Mother:	Orange juice?
Erica :	Uh huh. Not gonna spill it.

Erica was trying to say something quite distinct from her culinary preferences -- that she no longer knew two words ('eat' and 'drink') each of which occurred idiomatically with a subset of ingestable objects, but instead knew two words and a semantic rule which determined appropriateness. In effect, she had before a large set of semantic idioms. At some point probably shortly before the above conversation, the rule developed which eliminated all of those idioms.

From the several examples given so far emerges a pattern involving the child's use first of progressive idioms, then of generalized rules based on particular units of grammar and finally of regressive idioms which have not been reanalyzed and which need not be accounted for in a more specific way when the grammar is described in a more sophisticated form.

4. The process of learning. The learning process exemplified in language acquisition is unique among the learning situations which have been investigated. The few attempts which have been made to develop a psychological theory of learning which can account for language acquisition have been encumbered by the frameworks of stimulus——response and various traditionally recognized 'drives'. Language has often been said to be that which distinguishes man from all other animals, but I suspect that there are several other distinguishing characteristics and that some of them contribute to make language possible for man. Among them are such drives as exploration, curiosity, and self-fulfillment, and possibly even a learning drive. There are strong needs for variety and an antithesis to boredom. The prime reinforcement accounted for by this theory, namely the constant success~~ful~~, is sufficient to allow the activity of language learning to satisfy these drives.

It is possible that the more closely we can adapt teaching situations to duplicate this natural learning the easier will be the job of teaching. The learning outlined above requires no previous knowledge, no innate intuitions; there is not even the need to assume that the child has any idea of the enormity of the job he has undertaken or of the complexity of the end product. He procedes step by step, allowing each step to grow out of precisely that which he has mastered to date, never knowing that the next step won't be his last. All of the concepts necessary for final mastery grow out of the learning process itself.

A feature of this form of learning is the stable system of development which is shared by all children; the order of steps and the essential character of each step is dictated by the nature of the data. Within this framework, however, there is much room for vast idiosyncratic differences which in no way interfere with the attainment of the final goal. Perhaps the teaching of such broad frameworks is the only goal which education can usefully attain. Machine teaching programs which allow students to deduce their own generalizations after large numbers of instances of data are a step in the direction of this type of education.

Intensional Isomorphism and Deep Structure

Barbara Hall Partee

0. Introduction

Bar-Hillel in 1954 suggested that formal semantics as developed by such logicians as Tarski and Carnap had achieved insights and developed approaches which linguists might profitably make use of for the analysis of natural language. The long delay in taking up Bar-Hillel's suggestion has stemmed in part from the rejection by some linguists (notably Chomsky [1955]) of the claimed relevance of formal to natural semantics, and in part from the preoccupation of linguists with the more tractable syntax and phonology of natural language to the almost total exclusion of serious attention to semantics. Within the last few years, however, linguists have begun to be more concerned with semantics, and to give more than lip service to the principle that semantic considerations should have equal weight with syntactic ones in evaluating competing theories of grammars.[3] The present study is a preliminary investigation into the mutual relevance of some formal semantical notions developed by Carnap and the natural-language syntactic theory developed by Chomsky, with consideration of possible modifications of each.

The problem around which this study revolves is the analysis of sentences whose main verbs take as objects or complements (a linguists' distinction) sentences or propositons (a philosophers' distinction,) and in particular, the question of how closely the meaning of such a sentence is tied to the linguistic form of the embedded sentence. The verb believe is of central historical importance for such an investigation, because it was the analysis of belief-sentences that led Carnap to the important notion of intensional isomorphism, but it seems worthwhile to investigate as wide a range of such verbs as possible, because they show great variation in relevant semantic behavior.

I will begin with Carnap's notion of intensional isomorphism, and then discuss belief-sentences in the light of his proposals. Then I will backtrack to make some informal remarks about the Chomskyan notion of deep structure, and to suggest how it might be applied to such sentences. Since it will be readily apparent that neither intensional isomorphism nor deep structure provide satisfactory notions of equivalence for belief-sentences, the problem will then be to suggest alternatives. A number of other predicates will be examined before any generalizationa are suggested.

1. Carnap's notion of intensional isomorphism.

The notion of intensional isomorphism was introduced by Carnap in *Meaning and Necessity* in an attempt to handle some problematical aspects of the semantics of belief-sentences. In this section, with apologies to philosophers and logicians, I will recapitulate some preliminary features of Carnap's semantical systems, leading up to his statement of the problem of belief-sentences and his suggested approach to its solution.

1.1. Equivalence and L-equivalence.

For Carnap, the specification of a semantical system S typically includes syatactic rules of formation, semantical rules of designation for the descriptive constants of the system, and semantical rules of truth for sentences. In Carnap's examples the metalanguage is English, and the rules of designation for the individual constants and predicates are translations into English; likewise the sample rule of truth for atomic sentences simply requires that "the individual to which the individual ~~to which the individual~~ constant refers possesses the property to which the predicate refers." The fact that English is taken as the metalanguage with its own semantics presupposed raises immediately the question of the relevance of this kind of semantics to the analysis / of natural language, but for the moment we will brush this problem under the rug.

Two sentences A and B are said to be equivalent in a semantical system S if they are both true or both false in S, i.e. if $A \equiv B$ is true in S. Two sentences A and B are L-equivalent in a semantical system S iff $A \equiv B$ is L-true in S, i.e. $A \equiv B$ holds in every state description (possible world) in S. The notion of L-truth (in S), intended as an explication of necessary or analytic truth, amounts to truth which can be established on the basis of the semantical rules (of S) alone. The concepts of equivalence and L-equivalence are extended in a natural way from sentences to other designators such as predicates and individual expressions.

1.2. Extension~~s~~ and intension

Two designators are said to have the same extension in a semantical system S iff they are equivalent in S. Two designators have the same intension in S iff they are L-equivalent in S.

The extension of a sentence is taken to be its truth-value; of a predicate, the class it designates; and of an individual expression, the indiviudual to which it refers (taken as a special individual such as the null set or the number zero in case the individual expression is a description whose uniqueness condition fails to hold).

The intension of a sentence is taken to be the proposition expressed by it; the intension of a predicate is the property it designates; the intension of an indiviudal expression is what Carnap calls an "individual concept." These terms are made precise by the conditions for sameness stated above.

1.3. Extensional and intensional contexts

Two expressions occurring within a sentence are said to be interchangeable if substitution of one for the other preserves the truth-value of the sentence. If substitution moreover preserves the intension of the sentence, the two expressions are said to be L-interchangeable.

A sentence A is called extensional with respect to a certain occurrence of B within it if the occurrence of B_1 in A is interchangeable ~~interchangeable~~ with any expression B_2 which is equivalent to B_1. B_1 is then said to occur in A in an extensional context.

A sentence is intensional with respect to a certain occurrence of a subexpression if (a) the sentence is not extensional with respect to the subexpression and (b) the subexpression is L-interchangeable with any L-equivalent expression. The subexpression is then said to occur in an intensional context.

For example, a sentence constructed with any of the standard connectives $\sim, \vee, \supset$, etc., is extensional with respect to its components. A sentence constructed of a predicate letter and an individual constant is extensional with reppect to both the predicate and the individual constant.

On the other hand, a sentence constructed with a modal operator such as the necessity operator is not extensional, but is intensional, with respect to the expression within the scope of the modal operator.

1.4. Belief-sentences and intensional isomorphism

In first-order predicate logic, all sentences are extensional with respect to all their subparts; when the modal operator for necessity is added, all sentences are either extensional or intensional with respect to their subparts. But not all contexts are either extensional or intensional, and among the important exceptions are sentences about beliefs.

Carnap's argument for the non-intensionality of belief-sentences leads from a consideration of examples like the following:

(1) John believes that D

(2) John believes that ~~D*~~ D'

Carnap invites us to take as object language S a part of English that includes the predicat~~es~~or 'believes that' and some mathematical terms, and to take John's responses to questions about his beliefs as acceptable evidence for his beliefs. Then one can find some L-true sentence for which John professes belief, which can be taken as D (e.g. "Scott is either human or not human.") On the other hand, as Carnap says, "since John is a creature with limited abilities, we shall find some L-true sentences in S for which John cannot profess belief." Then we take as ~~D*~~ D' some such sentence. Then D and D', both being L-true, are equivalent and L-equivalent; yet since (1) is true and (2) is false, D and D' are neither interchangeable nor L-interchangeable in the context of (1). Hence the belief-sentence is neither extensional nor intensional with respect to its subsentence D.

Carnap proposes the notion of "intensional isomorphism" as a possible way to capture a relation sufficiently much stronger than L-equivalence to guarantee interchangeability in belief contexts. Two sentences are intensionally isomorphic if they are contructed in the same way out of elements that are L-equivalent down to the smallest units. (Carnap gives a fuller definition though not an exact one, since an exact one would require a fully specified semantical system or systems within or between which isomorphism could be defined.) Carnap then suggests that the sentence 'John believes that D' in S can be interpreted by the following semantical sentence:

(3) [15-1.] "There is a sentence $\mathfrak{S}_i$ in a semantical system S' such that (a) $\mathfrak{S}_i$ in S' in intensionally isomorphic to 'D' in S and (b) John is disposed to an affirmative response to $\mathfrak{S}_i$ as a sentence of S'." (P. 62).

Then if D and D' are two intensionally isomorphic sentences, (1) and (2) are equivalent in S and furthermore L-equivalent in S since their equivalence follows from [15-1], which is a rule of S.

Carnap suggests that his analysis of belief-sentences might be regarded as a first step in the logical analysis of propositional attitudes. To extend the analysis to include terms about doubt, hope, fear, surprise, etc., would simply require the development and refinement of other dispositional notions analogous to the notion of "disposition to assent to a sentence" suggested for belief-sentences.

2. Problems about belief-sentences

A number of distinct though interconnected problems arise in the analysis of belief-sentences and other sentences about propositional attitudes. The one I am most interested in here is the question of what kind of equivalence between two sentences will suffice to make them interchangeable in a belief-context. An examination of some objections to Carnap's solution will lead us to the question of what counts as evidence for the truth of a belief-sentence and the question of whether the object of believe should be construed as a sentence or a proposition.

2.1. The substitution problem

Mates (1950) constructed a counterexample to Carnap's analysis, using an argument quite similar to Carnap's argument (stated above, 1.4) for the non-intensionality of belief-contexts. Mates considers sentences like the following:

(4) Whoever believes that D, believes that D.

(5) Whoever believes that D, believes that D'.

where D and D' are abbreviations for two different sentences which are intensionally isomorphic (or synonymous by any other explication). According to Carnap's account, if D and D' are intensionally isomorphic, then so are (4) and (5). Hence (4) and (5) would be L-equivalent. But as Carnap acknowledges, in a later article included as Appendix C to the enlarged edition of Meaning and Necessity, "However, while [4] is certainly true and beyond doubt, [5] may be false, or, at least, it is conceivable that somebody may doubt it." The argument holds for any relation between D and D' short of inscriptional identity, so it is not simply a matter of looking for a relation a little stronger than intensonal isomorphism.

But in Appendix ~~D~~ C, Carnap gets out of Mates"s trap by a ploy he attributes to Church, namely by revoking his earlier stipulation that we take a person's disposition to assent to a sentence as definitive evidence for his belief. If that assumption is abandoned, and belief taken instead as a theoretical construct for which many kinds of evidence may offer inductive support, one can simply require (5) to be true for intensionally isomorphic D and D', and discount any apparent evidence to the contrary. The question of what constitutes evidence for belief is therefore of fundamental importance, and will be taken up in the next section.

2.2. Evidence for belief

2.2.1. Assent to sentences

Carnap's assumption in Meaning and Necessity that a person's beliefs can be inferred directly from his dispositions to affirmative responses to presented sentences is not quite the same as equating that a person believes with what he says he believes, since the subject's understanding of the predicate "believes that" is not brought into the matter at all on Carnap's analysis. But in addition to letting in Mates's problem, Carnap's assumption has other undesirable consequences which also need to be avoided by an adequate theory of belief-sentences.

(a) Non-reductionism. One kind of objection to the assumption is voiced by Carnap in his article in Appendix C, namely that a term like "believes" cannot be reduced to any equivalent expression in the language of observables. This,is. I suppose, an aspect of the general inadequacies of logical positivism, and is related to Chomsky's insistence on linguistic competence (a theoretical construct) as opposed to performanc e (directly observable data) as the basis for linguistic theory.

One example of the possible misleadingness of disposition to assent as criterial for belief would be the chronic liar. (If his dispositions to assent really reflected his beliefs, he should presumably be called not a liar, but a fool.) For another example, consider the sentence "John believes that a stalagmite is always larger than the corresponding stalactite." Assume that John and his interlocutor, to all appearances, speak the same language, namely standard English, and that John is disposed to assent to the embedded sentence. It may nevertheless be false that John believes that a stalagmite is..., because of the (non-observable) fact that John has unwittingly got the terms "stalagmite" and "stalactite" mixed up. Perhaps it would be argued that such differences in language are always potentially observable, but it [illegible] that at the very least, a person's language would have to be [illegible] in the basis of purely observational data in order for a person's beliefs to be so determinable.

(b) Dogs. If "John believes that D' means that John is disposed to assent to a certain sentence, then we would never be allowed to assert of a dog, at least of a non-talking dog, "Alf believes that his mistress is in this building." This might not be too consequential a limitation, since I for one would be willing to be limited to assertions like "that dog is acting as if he believed that...". But even that sentence does not represent anything I would want to assert under Carnap's explication, since it would mean "that dog is acting as if he were disposed to an affirmative response to ...", which is not at all what I have in mind if I say that that dog is acting as if he believed such-and-such. The things that I take as evidence for what a dog believes (or for thinking that he believes anything) include only marginally his responses to presented linguistic stimuli--a much more typical bit of evidence for the exampke cited would be his refusal to be budged from the doorway until his mistress emerged. An adequate theory of evidence for beliefs must at least allow someone to be able to claim that dogs have beliefs without thereby ascribing to them any linguistic ompetence.

(c) Transparency. The assent criterion is manifestly inadequate for examples like the following, which exhibit what Russell and Quine call the transparent reading of the verb.

(6) The students believe that the chancellor has more power than he really does.

(7) Tom believes that you and I are sisters.

(8) Jones believes that that new mistress of Smith's is Smith's wife.

In such cases the belief-sentence does not provide an extractable embedded sentence appropriate for presentation to the alleged believer, nor does there seem to be any uniformly effective procedure for reconstructing an appropriate presentation sentence. Hence any account ~~for~~ of belief-sentences that attempts to include the transparent cases (which are in other respects considered logically simpler than the opaque cases) is doomed if it requires belief to involve assent to the actual embedded sentence (or a sentence intensionally isomorphic to it.)

2.2.2. Belief as a theoretical construct

Carnap's later position (1954) is that belief is a theoretical construct for which evidence such as disposition to assent offers inductive support but not conclusive indication. He there leaves open the question of what other evidence counts as relevant, and appears to leave room for a reasonable account of liars, dogs, and those of us who tend to confuse "stalagmite" and "stalactite". He also, and explicitly, leaves open the question of whether a proposition or a sentence is the more appropriate object of belief. The main condition he imposes on the notion of belief in the later article is that the problematical Mates sentence,

(5) Whoever believes that D, believes that D',

should count as logically true when D and D' are synonymous. Any psychological evidence to the contrary would ipso facto be untrustworthy evidence.

Such a stipulation is quite appropriate for the philosopher engaged in rational reconstruction. But the linguist, although he may agree wholeheartedly that "believes" is a term for whose correct application no single kind of observational evidence is criterial, is not thereby free to discount a priori whatever observational evidence happens to conflict with his favorite hypothesis. Hence as a linguist I am simply unable to accept Carnap's way out of Mates's problem, since I am unable to dismiss the apparent counterevidence (Putnam, [1954]) that not everyone who believes, for instance, that all Greeks are Greeks believes that all Greeks are Hellenes. (It may be possible to argue one's way out of such counterevidence, as Sellars (1955) attempts to do, but I cannot simply discount it as Carnap is prepared to do.)

2.3. Inconsistent beliefs.

Carnap's approach allows the possibility of a person's holding inconsistent beliefs. He makes this explicit in his discussion of the example of John believing that D but not believing that D', for various sentences D' L-equivalent to D: He says, 'This does not necessarily mean that he commits the error of believing their negations.' Some logicians would prefer to narrow the concept of belief by putting a requirement of consisten on a person's beliefs. Certainly if someone persisted in making statements like "I believe that Scott is the author of Waverly and also that Scott is not the author of Waverly", "I believe that 2 is not equal to 2", and the like, we would question either his sincerity or his understanding of the word "believe". On the other hand, it is not so difficult to imagine a person sanely and sincerely asserting something like "I believe that taxes should be lowered, that welfare and Medicare benefits should be increased; that more state aid should be given to schools and to freeway construction; and that the government should keep a balanced budget," along with whatever unstated assumptions it might take to make those beliefs inconsistent (I do not know anything about the logic of "should" but I am assuming that sentences with "should" can be inconsistent.) Since belief is a paradigm case of a psychological predicate, perhaps it should not be stretching etymology too much to suggest that some people tend to be more logical and others tend to be more "psycho."

The decision one makes on the question of whether to admit inconsistent beliefs will of course affect one's analysis. A formal system which allows a person to be said to hold inconsistent beliefs without thereby believing everything cannot be as simple as a system which disallows such a possibility can be, particularly if one wants to allow some inconsistent beliefs, but not admit that someone can, e.g., believe a proposition of the form "A and not-A". But if all inconsistent beliefs are ruled out, the correspondence of the formal system to its purported explicandum ~~explication~~ in natural language becomes moot: if a person professes to believe a set of sentences which are independent (in the sense that no one of them can be deduced from the remainder of them) but inconsistent, it is hard to see how one would tell which one(s) he "really doesn't believe". I can readily imagine getting him to give up one of his beliefs, but that very phraseology suggests that it was previously indeed a belief of his.

The decision one favors on the inconsistency question is likely to correlate with one's intuitions about what substitutions in belief-contexts preserve truth and whether the logical consequences of a person's beliefs are automatically also beliefs of his. For instance, if all the logical consequences of John's beliefs are also John's beliefs, then (a) a person who has inconsistent beliefs must believe everything, and (b) logical equivalence is a sufficient condition for substitution in a belief-context. However, the inconsistency quesoion and the substitution question appear to be logically independent, at least if the consequences of A's beliefs are not necessarily A's beliefs.

2.4, Sentences or propositions.

The question of whether belief is a relation between a person and a sentence or between a person and a proposition is fundamental for the substitution problem and has ramifications far beyond it besides. Carnap is inclined to take the object of belief to be a sentence (in a semantical system) but acknowledges Church's suggestion that it might be treated as a proposition, and leaves the issue open. Carnap's own notion of intensional isomorphism is applicable only to the analysis of objects of belief as sentences.

Some of the points that were raised concerning evidence for belief are relevant here. For instance, whatever it is that I might mean if I talk about what a dog believes, it certainly does not invlove any system of canine semantics. Hence for dogs the appropriate object of belief would be a proposition and not a sentence.

The total Carnapian exclusion of inexplicit or unexpressable beliefs does not seem to me to be a very serious matter; a complete account of how "believes" is used in ordinary language ought to include them, but it would not seem unreasonable if they had to be treated quite differently from verbally expressable beliefs. What does seem to me more of a concern for the analysis of natural languages is the extent to which the notion of intensional isomorphism leads to a kind of accidental language-dependence in the ascription of belief. Take a sentence like "Jones believes that Smith is hungry": this could be true if Jones is an English-speaker, but not if Jones speaks, say, Spanish or French or German, where the noun for "hunger" is used with the verb for "have". The same sorts of non-isomorphism crop up with many other expressions which have no morpheme-by-morpheme translations between various pairs of languages. In fact if "be" and "have" are taken as primitives in English, and their nearest equivalents in other languages are also taken as primitives, their designation rules would undoubtedly be different in every language. Then no belief-sentence involving "be" or "have", including "Jones believes that the earth is round", would be true if the believer's language was different from the language in which the belief-sentence was stated.

At least a partial solution to this problem would be to say that terms like "be" and "have" which have a wide range of use are actually multiply ambiguous, with the number of distinct subterms to be determined by inter-linguistic comparisons. Most prepositions and the most common verbs would no doubt have to be split up into many subterms if there was to be any hope of achieving real universality; and even then it is only cases like "the earth is round" which would be handled, not those like "Smith is hungry." The suggested partial solution is unsatisfactory on linguistic grounds as well. It is artifical to determine ambiguity within a language on the basis of cross-language comparisons, since a naive langgage-learner (e.g. a child) has in general no access to data from outside his own language, and his internally constructed system therefore takes no account of such data (except for linguistic universals which can be regarded as in some sense "programmed" into his innate competence.)

In any case, there are other arguments, such as the existence of transparent readings as in examples (6) - (8) where there is no appropriate contained sentence, which suggest that the object of belief must be a proposition and not a sentence.

But suppose that on the basis of such considerations we were to take the object of belief always as a proposition, and suppose we take the model-theoretic definition of a proposition as a function from possible worlds to truth-values. Then since any two logically equivalent sentences denote the same proposition, we would immediately be forced into saying that logical equivalence suffices for substitution, so that "believes that ..." is after all an intensional context.

Since I find myself unwilling to give up transparent examples like (6)-(8) but equally unwilling to accept the conclusion of the preceding paragraphs, I am forced to conclude that there are two distinct uses of the term "believes" (or possibly a continuum between two poles.) If I state that John believes that Bill is in charge here, I may be doing either of two things. I may be doing something very close to quoting an statement John made, in which case the object of "believes" is a sentence and I might just as well have stated, albeit unidiomatically, that John believes "Bill is in charge here." On the other hand, I may be treating John like a dog--that is, I may be no more relying on any of John's utterances or reactions to utterances than I would be in ascribing belief to a dog; in such cases, the object of "believes" is a proposition and substitution of logical equivalents indeed preserves truth.

I think that in one sense the recognition of this duality of use is not at all new, since it is very closely tied to the ambiguity of examples like(9):

(9) John believes that one of the girls will fail the test.

But it is perhaps worth making the connections explicit: "Dog-belief=transparent belief=propositional-object belief; substitution of logical equivalents preserves truth, and actual sentences have no special status among types of evidence." "Quotative-belief =

opaque belief=sentential-object belief; not even intentional isomorphism provides a strong enough condition for truth-preserving substitutivity, and actual sentences, either pronounced or assented to, are particularly important if not indispensable as evidence.

Quine in Word and Object (p 200ff) suggests that if the notion of proposition is to have any usefulness at all, it should be as object of the propositional attitudes. But then he uses arguments like Mates's to show that it is futile to try to find any reasonable criterion for identity of propositions, apparently conflating propositional-object and sentential-object belief.

The two uses of "believes" can lead to semantic ambiguity, as in the case of (9) above, but it seems probable to me that in many cases the two uses amount to the same thing (if, for instance, our evidence for a person's belief is in fact something he said, and we happen to use the same wording in reporting his belief). Therefore for many examples of belief-sentences it will not be possible to decide from the sentence alone which use of belief is involved, and there may be no semantic ambiguity. But I do not believe that the existence of a body of "neutral" cases invalidates the distinction.

Before turning to the consideration of linguistic "deep structures" for belief-sentences, I want to expand the discussion to include some other examples of propositional attitudes.

3. Other predicates

Verbs and other predicates which take sentences or propositions as one of their arguments exhibit a wide range of behavior with respect to the kinds of matters examined above in connection with "believes." We will examine here for a number of predicates whether the wording of the embedded sentence is taken to reflect the actual wording of some prior discourse;

whether the predicate can be applied to dogs and other non-linguistic species; what kinds of substitutions preserve truth; and whether the predicate seems to have two are more well-defined senses (or perhaps uses).

3.1. Emotives. Certain verbs and adjectives express a relation between an animate being and what certainly appears to be a proposition rather than a sentence. The Kiparskys (1968) call these "emotives" and point out that the embedded sentence is always presupposed to be a fact. Examples of emotive predicates, all taking *that*-clauses, include *regret*, *hate*, *be surprised*, *be amazed*, *be sad*, *be glad*, *be upset*, *be delighted*. (These predicates also take infinitival complements, and some of them also take gerundives, but we will be concerned only with *that*-clauses.) The emotives all seem to be clearly at the propositional-object end of the scale: dogs can be surprised, etc.; there is no implication from a sentence like (10)

(10) Andy was glad that the job opening had already been filled.

that the subject either uttered or heard any sentence resembling the embedded one; and substitution requires only logical equivalence.

3.2. *Verbs of inference*. At the other end of the scale, but equally clear-cut, are verbs like *deduce*, *prove*, *establish*, *show*, *discover*, which we might call "verbs of inference."

(11) John proved in 3 lines that all left-inverses in a group are right-inverses.

Here the embedded sentence is virtually a direct quotation (although the pronoun-shifts and other transformations associated with indirect discousse do apply), and the evidence for the truth of the whole sentence crucially involves an overt occurrence of (something very close to) the embedded sentence. For truth-preserving substitution, logical equivalence is blatantly too weak. This is a case where intensional isomorphism might be the right strength, although the allowable differences due to "merely syntactic devices" would have to be restricted to those syntactic differences which did not count as differences within any formal system.

Some verbs of inference can take as subject a noun phrase denoting some kind of evidence as an alternative to a subject which, as in (11), denotes the agent of the inference.

> (12) The fact that the bullets pierced the door ~~as~~ shows that ~~they~~ the police couldn't see who they were shooting.

In Fillmore's case grammar terms, we can say that such verbs take a sentential object and either an agent or an instrument (perhaps stretching that term slightly), and either of the latter two can be the subject. In some sentences like (13) below, an animate subject may in fact seem more an "instrument" than an agent.

> (13) ~~Sam~~ Sam proved that he was involved when he referred to Miss Faust as "Maizie."

In (12) and (13) the sentential objects of the verbs of inference are not understood as related to any overt occurrence of related sentences, as was the case in (11). The uses of "show" and "prove" in (12) and (13) seem to appeal to a commonsensical notion of what follows from what, rather than to a formal system of deduction as in (11). It is hard to formulate reasonable candidates for substitutional criteria for cases like (12) and (13). Perhaps logical equivalence might do, but it is hard to be certain, since commonsensical analogues of formal notions like deducibility tend to break down when confronted with non-standard cases. For example, I am not sure whether (14) should count as equivalent to (13) or not:

(14) Sam proved that he was involved and (that) Bill either was or was not at the scene the previous day, when he referred to Miss Faust as "Maizie."

Perhaps the clearest verb of the class is *deduce*, which always requires an agentive subject and for which logical equivalence is definitely too weak to guarantee substitutivity. *Infer*, surprisingly, cannot be included in this class, because its object-clauses seem to be propositions rather than sentences. Thus (15) is ambiguous, but if *infer* were replaced by *deduce*, *establish*, or the like, only the self-contradictory sense of the embedded clause would be possible.

(15) Jones inferred that your yacht was longer then it was.

It is interesting that *infer* is non-factive, while all the verbs that I have called 'verbs of inference' are factive; *infer* seems to denote a more subjective process of inference than the others. Compare the normalcy of (16a) with the oddity of (16b).

(16) Because he considered only Mary's remarks, he incorrectly

{(a) inferred }
{(b) established} that Sam was to blame.

An incorrect inference (in the subjective sense) is an inference; an incorrect proof is not a proof.

In sum, then, the verbs of inference (excluding *infer*) in their strictest use take sentences as object and have very strong substitutivity requirements; they thus occupy the opposite pole from the emotives. These two classes between them provide relatively unambiguous examples of the two uses of an ambiguous verb like believe.

3.3. Verbs of communication.

One would expect that a verb like *say* or *tell* would be even more literally quotative than a verb like *deduce*, but that is not the case when the verbs are used with *that*-clauses, or what is normally called indirect quotation. All of the verbs *say*, *assert*, *report*, *allege*, *tell*, *suggest*, *hint*, *imply* can fit naturally into the frame of example (15) above without forcing the contradictory reading of the embedded clause. In fact, while for *say* and most of the others the embedded clause can be a quotation except for mandatory shifts in indexicals, for *hint* and *imply*, such a near-quotative reading seems to be impossible. For example, a sentence like (17) would be regarded as false, or at least misleading, if what Nixon actually said was "the new South Vietnamese government will include Communists."

(17) Nixon hinted that the new South Vietnamese government would include Communists.

(The situation is complicated by the fact, pointed out to me by Larry Horn, that if the embedded clause has *might* in it, the hint can be a near-quotation.)

It appears that these verbs, when used with a *that*-clause, are used to report the content of a communication, and not its verbatim form. But there are other verbs of communication, which could be called "manner-verbs of communication", which take *that*-clauses that seem to be what I have been calling "near-quotes", i.e. quotations except for shifts in indexicals. Sentences (18) and (19) exemplify this class, which includes *shout*, *whisper*, *scream*, *hiss*, *hoot*, *giggle*, *bark*, etc.

(18) Jed hollered that them brown cows was back in the corn patch again.
(19) She giggled that she would feel just too, too liberated if she drank another of those naughty martinis.

Since these verbs emphasize the manner of the communication, it is not surprising that the form as well as the content of the embedded clause is significant. Note that the verbs cannot be analyzed as "communicate by giggling", etc., since (20) and the like are quite odd, unless the dog is assumed to have a bark-language:

(20) Fido barked that someone was in the front yard.

All of the verbs of communication refer, by virtue of their central meaning, to some overt utterence or other overt communication; but only for the manner-verbs of communication is it the case that the embedded *that*-clause must be a near-quotation of the overt utterance. Thus it would seem that the normal verbs of communication take propositions as objects, but the manner-verbs of communication sentential ones.

3.4. *Epistemic predicates.*

Believe shares important semantic properties with *know*, *realize*, *forget*, *remember*, *be certain*, *think*, *suppose*, *doubt*, *be aware*. Among other things, it seems to share its ambivalence in usage between a sentential and a propositional embedded clause. Thus although Chomsky [DS, SS and SI] cites examples with *realize* that fit Mates"s schema for non-substitutivity of synonyms, it would be wrong to conclude that the object of *realize* is always a sentence rather than a proposition, because *realize* also passes the dog-test:

(21) Fido finally realized that the children were nowhere around the house.

And although (22) is odd, the oddness is due to the factivity of *realize*, and not to a requirement that the embedded clause be regarded as a sentence. Hence (23), which avoids purporting as factive a falsity, is perfectly acceptable with its *that*-clause interpreted as an embedded proposition.

(22) I realized that your yacht was longer than it is.

(23) I didn't realize that your yacht was as long as it is.

With this brief attempt to put *believes* into perspective among verbs that take *that*-clauses, let us turn to the question of the linguistic "deep structure" for such constructions.

4. *Deep Structure*.

In Chomsky's earliest formulations of transformational grammar, e.g. Chomsky (1957), it was emphasized that in postulating underlying representations and transformations, the justification must always be purely syntactic. Examples abound of resulting syntactic analyses that are quite unwieldy as bases for semantic interpretation. For example: (a) Syntactically, the contrast between definite and indefinite noun phrases was always regarded as simply a minimal contrast in the article position. (b) Quantifiers, demonstratives like *this* and *that*, the articles, and words like *only* and *other*, were all simply introduced by phrase structure rules as components of the "determiner" of a noun phrase. (c) All adjectives were introduced in predicate position, so that the attributive use in (24) would be derived from (25):

(24) Small elephants are big.

(25) Elephants which are small are big.

Furthermore, since the formation of relative pronouns was assumed to involve deletion of a noun identical to the head noun, (25) would itself be derived from the semantically inappropriate pair of sentences (26):

(26) Elephants are small.
Elephants are big.

(d) In the earliest treatments, negative sentences were optional transforms of positive ones. Klima (1964) showed purely syntactic motivation for postulating a deep structure NEG morpheme for negative sentences, but his system included an optional some-any suppletion transformation (limited primarily to negative contexts) which allowed (27) and (28) to be derived from the same underlying representation:

(27) John couldn't solve some of the problems.

(28) John couldn't solve any of the problems.

4.1. Deep structure semantics.

By the time of Chomsky (1965), Chomsky had been convinced by the arguments of Katz and Postal (1964) that deep structure as established by "purely syntactic motivations" would turn out to be the only level of syntactic structure relevant to semantic interpretation. That hypothesis rapidly gained favor to the point of becoming widely regarded as criterial rather than empirical, so that transformations like Klima's some-any rule came to be regarded as untenable.

Although semantically inappropriate analyses liek those mentioned above were not immediately replaced, the general notion of deep structure did and does look basically quite promising as a way of coming close in many cases to the spirit of Carnap's "mrwely syntactic devices". Thus if one considers the problem of defining intensional isomorphism for natural languages, deep structurd would be the appropriate level to require sameness of structure on. The following pairs are typical cases of superficially distinct structures with identical underlying representations:

(29) (a) That Mary wore a wig surprised Timothy.

(b) It surprised Timothy that Mary wore a wig.

(30) (a) Sam turned out the light.

(b) Sam turned the light out.

But it has been widely disputed of late whether the Katz-Postal hypothesis really holds (for a survey of some of the arguments see Partee (1969).) The following sets, which would classically be regarded as transformationally related, illustrate the problems:

(31) (a) Few rules are explicit and few rules are easy to read.
(b) Few rules are both explicit and easy to read.

(32) (a) It is particularly easy to get this baby into these overalls.
(b) This baby is particularly easy to get into these overalls.
(c) These overalls are particularly easy to get this baby into.

Sentences with believe in fact offer an interesting case in point. There is a (disputed) transformation familiarly known as "subject-raising" which would transform (33) into (34).

(33) Tom believes that Cicero denounced Catiline.

(34) Tom believes Cicero to have denounced Catiline.

But Quine argues in Word and Object (pp. 145-50) that (33) and (34) are not synonymous, in particular that only in (34) is Cicero in purely referential position. Yet the syntactic evidence for subject-raising is strong; among other things, it provides the only reasonably account for sentences like (35) and (36).

(35) Tom believes there to have been an earthquake recently.

(36) Susan believes it to be likely that no one will show up.

Sentences like those two simultaneously suggest that Quine's semantic intuition may be wrong, since there and it certainly cannot be taken as referential. My own feelings about (34) are not strong, though I am inclined to regard it as ambiguous, with a slightly greater tendency for Cicero to be regarded as referential than in (33). But (37) below seems to me definitely ambiguous, which again argues against Quine's interpretation.

(37) ~~[illegible]~~ John believes a Communist to have been at the heart of the plot.

4.2. Generative semantics.

The theoretical approach which is associated with the names of McCawley, Lakoff, Ross, Postal, and Bach, and which often goes under the name of "generative semantics", can be thought of as a deep structure semantics pushed to deeper structures. Within the framework of model theoretic semantics it makes no sense to call those deeper structures "semantic"[6]; that terminology is probably just a carryover from Katz-type semantics. At any rate, the proponents of the generative semantics approach suggest~~s~~, among other things, having very different deep structures for definite and indefinite noun phrases, assigning the same deep structure to syntactically disparate (putative) paraphrases such as "Seymour sliced ~~[illegible]~~ the salami with a knife" and "Seymour used a knife to slice the salami;" assigning appropriately different deep structures to sets like (31) and (32); etc. One of the key differences between Chomskyan deep structure and Lakovian abstract structure is that Chomsky regards deep structure as the level at which virtually all actual lexical items are inserted, but the corresponding terminal elements in Lakoff's system are abstract semantic primitives, with lexical insertion a complex transformational process. Actual lexical items are thus part of relatively superficial structure in Lakoff's system. Since the notion of 'intensional isomorphism' is relative to the smallest units of a system, it would have quite different interpretations in the two systems.

It is impossible to do justice in a short space to the prolific and stimulating flow of ideas that has resulted from the generative semantics approach. Let me then overgeneralize and say that it looked most plausible when it presented "semantic-looking" abstract deep structures for classically difficult cases, accompanied by arguments for independent syntactic justification of those semantically appropriate structures. Some basic problems arose in attempting to solve the problem of how the syntactic transformations would be restricted to guarantee that a given abstract deep structure would be mapped only onto the right surface structure. For instance, sentences (31)(a) and (b) would have the same deep structure in the "classical" theory; it was suggested in Partee (1970) that if a generative semanticist assigned them different deep structures, he would still have to separately prevent the usual conjunction-reduction transformation from mapping (31a) onto (31b). Lakoff's response (Lakoff (1969)) was in part to add the notion of "global constraint" to his system, so that certain aspects of the "semantic" deep structure could in effect control the subsequent syntactic processes. Whether and how the resulting system differs from alternative theories is debatable and debated.

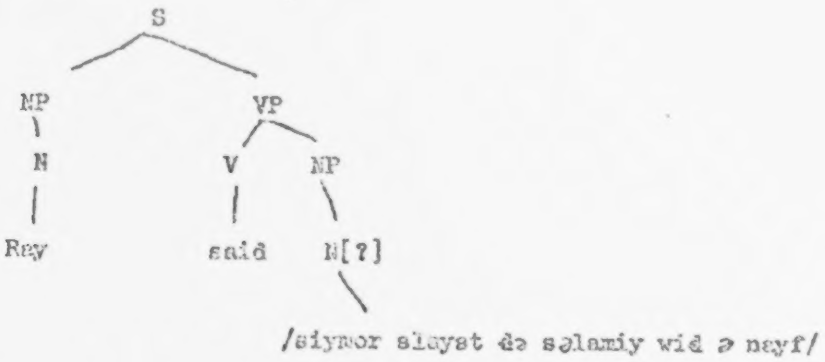
4.3. Interpretive semantics. Again oversimplifying, one might describe the "interpretive semantics" approach of Jackendoff, recent Chomsky, and others as an attempt to rectify the deficiencies of the Katz-Postal type of deep-structure semantics, not by pushing syntactic deep structure deeper, but by letting semantic rules take account of surface structure as well as deep structure, with the latter determined on the basis of "purely syntactic arguments" as in the earlier theory. Then sets like (31a,b) and (32a,b,c) could still have single deep structures, but those structures would no longer be purported to be the sole determinants of meaning. Interpretive semantics, or the "surfacist" approach, does not mean using only surface structure; and on some accounts it may allow all levels of structure to be involved -- e.g. some semantic rules might operate in the transformational cycle. It is partly for this reason that it is difficult to establish whether generative semantics (with global constraints) and interpretive semantics might be different.

4.4. Applications to verbs of propositional attitudes.

In the first place, it seems to me that quotation presents a serious problem to standard deep-structure semantics, and likewise to generative semantics. The reason is that part of the meaning of a sentence with a direct quotation in it involves the surface form of the quoted sentence, so that one might want to regard the quoted sentence as an unanalyzed phonological or graphic string and represent it directly as such in the deep sturcture. For instance, one might consider representing the deep sturcture of (38) along the lines (very roughly) of (39):

(38) Ray said, "Seymour sliced the salami with a knife."

(39)



I have no idea what category could be suggested for the quotation; the essential feature is that it would not be given internal syntactic structure.

Such a proposal looks particularly appropriate, by the way, for sentences like (40):

(40) The little engine went, "Puff-puff, chug-chug, toot-toot."[3]

But when the quotation is of an English sentence, the syntactic and semantic content of the quoted sentence is also relevant to the meaning of the total sentence, e.g., for the understanding of *she* in (41), *one* in (42), the ellipsis in (43), and the word *opposite* in (44).

(41) When the surgeon shouted, "I need the nurse!", *she* came right in.

(42) When the surgeon said, "Give me the scalpel!", she handed him the wrong *one*.

(43) When he said, "Leave!", she wouldn't [_____].

(44) When he said, "Turn right," she did the *opposite*.

Hence a structure in the style of (39) is inadequate for lack of internal structure; but as soon as the phonological string is replaced by a structural description, there is no way of distinguishing the original quotation from any synonymous non-identical quotation, e.g., on Lakoff's account of synonymy, (38) would then have the same deep structure as (45):

(45) Ray said, "Seymour used a knife to slice the salami."

If the subsentences of (38) and (45) were synonymous (I don't think they are, but any synonymous pair would do), then there ~~are~~ would be no way to assign them different deep structures without somehow including the phonological or other surface inscriptional form as part of the deep structure, in which case that structure can hardly be called "deep", "abstract", or "semantic".

I have gone on at length about quotation because I think it is simply a clearer form of the sentential-object use of verbs like believe, also exemplified by indirect quotation with verbs like shout, and by the verbs of inference. I think that the generative semantics approach has shed interesting light on the propositional-object cases, which seemed from the viewpoint of the classical theory much harder to give semantically appropriate deep structures for. But it appears that in the process the "easier" sentential-object cases were made impossible to account for.

As a coroliary to this observation, it follows that ambiguities which depend on the distinction between propositional and sentnetial object are not going to be uniformly representable in a generative semantics framework.[8] AS a sample problem, I would pose the Russellian comparatives like (35); this is a doubly difficult problem because comparative ~~io~~ constructions in general have proved very difficult to analyze syntactically. But the analysis ought in principle to be of the same kind as the analysis of "John didn't know that my brother was my brother" and the like.

Another problem for standard deep-structure semantics is raised as soon as we shift from direct to indirect quotation. I think it has long been assumed that there are certain "indirect-discourse transformations" which make sequence-of-tenses adjustments and other changes in indexical terms. It would certainly be missing important regularities not to relate

(46)(a) John said, "I am right".

(b) John said (that) he was right.

But if there are such transformations, they have no source to apply to in examples like (47), assuming a principle prohibiting unrecoverable deletions:

(47) Tom said that you and I were sisters.

Various suggestions might be made about (47), but the same suggestions should then be applied to (46.b). Possibly (46.b) could be treated as ambiguous, with one derivation from (46.a) and another analogous to (47). But if (46.b) is not derived from (46.a), there must be some semantic rules to show their relation.

And it is by no means self-evident that semantic and syntactic distinctions should always parallel one another. As far as I can see, the distinction between sentnetial and propositional that-clause objects is not at all a syntactic one. The semantic distinctions concernig substitutivity, the dog-test, etc., discussed in section 3 above, do not appear to have any independent syntactic correlates (though I may simply not have looked hard enough). The linguist has generally used the symbol "S" without distinguishing sentences from propositions, because there have been no syntactic grounds for proliferating categories in that way.

A related point is that the substitutivity conditions in particular do not lend themselves to natural statements in any framework in which "semantic interpretations" are conceived of as "objects" representable by anything like a tree structure. A given sentence will participate in a great many semantic relations with innumerable other sentences; all of these relations are part of our understanding~~;/ss~~ of the sentence, as are the truth-conditions for the sentence. To look for "the semantic representation" of a sentence seems to me misguided; questions like the question of the conditions for truth-preserving substitutions of that-clauses in belief-sentences seem to require a much richer notion of semantics, and therefore seem to me worth pursuing much farther than I have managed to take them here.

FOOTNOTES

1. A linguist would, however, take issue with Montague's opinion that syntax is of no great interest except as a preliminary to semantics (Montague (1970)). In spite of the notorious difficulty of making the notion of "well-formed sentence" precise for natural languages, it is a striking nad well-confirmed fact that all natural languages share many highly specific syntactic properties that lead the linguist toward the postulation of a notion of "possible natural language" that is much narrower and more highly structured than the general notion of "possible language". I would not as a linguist argue against the complaint voiced by Montague and by Dana Scott among others that transformatial linguists have not made much progress toward a rigorous formalization of their theories of grammar; there are still too many unresolved problems at a pre-formal level. I would argue only against making an inference therefrom that the aims and mthods of linguistics are misguided.

2. Possible world semantics makes the interpretation of embedded propositions like "your yacht is longer than it is" clear; the sentence can be regarded as semantically equivalent to "your yacht is longer than it is in the real world." Then if in the real world your yacht is 30 feet long, the sentence is true in all worlds in which your yacht is more than 30 feet long, and false in all those in which it is not (I leave aside the question of worlds without your yacht.) So "I thought that ..." means roughly that I thought this world was one of those long-yacht worlds.

3. It is sentences like these that can make first-grade readers and the like very difficult to analyze syntactically. Joyce Friedman and I noticed, when she was starting to write a transformational grammar for Yngve's sample text Engineer Small, that the verb go as used in (40) seems to allow as its complement any phonetic sequence that is not and ordinary sentence of English; it's hard to characterize that restriction in a grammar of English. (A generation younger than mine has dropped that restriction on go.)

4. Let me hasten to add that I am singling out the generative semantics approach for criticism because it's the only one in which any attempt has been made to account for any of these problems, as far as I know.

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ON RESTRICTING THE BASE COMPONENT OF TRANSFORMATIONAL GRAMMARS*

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ABSTRACT

We investigate the effects of placing various restrictuions on the base component of a transformational grammar as defined by Chomsky (1965). It is shown that by utilizing the so-called filter function of transformations the descriptive power of transformational grammars can be preserved unreduced even when their base components are subjected to drastic restrictuions.

1. Introduction

In Peters and Ritchie (19) we defined in a mathematically precise fashion the notion *transformational grammar*, modeling essential features of these grammars as discussed informally in Chomsky (1965). Such a grammar was there defined to contain a *base component* consisting of a phrase structure grammar -- an unordered set of rewriting rules of the type $A \rightarrow \omega / \varphi \;\text{——}\; \psi$ (the symbol A may be rewritten as the (non-null) string ω if it appears between φ, ψ). These rules allow one to derive strings of terminal symbols from the initial string #S# and to assign one or more labeled bracketings to each derived string showing its composition as a sequence of phrases. The resulting set of labeled bracketings (*Phrase-markers*) serves as input to the *transformational component* of a transformational grammar, which consists of a linear sequence of *grammatical transformations* each of which converts labeled bracketings into labeled bracketings in a manner we briefly summarize here. A grammatical transformation consists of a *structural condition* and a set of *elementary transformations*. An input labeled bracketing is first factored into a sequence of subparts so that the factorization satisfies the structural condition; such a factorization is called a *proper analysis* of the labeled bracketing for the transformation. If the input labeled bracketing has no proper analysis, the transformation gives as output the input labeled bracketing. Given a proper analysis of the input, the elementary transformations are applied to its factors. Each elementary transformation will either a) *delete* a sequence of factors, b) *substitute* one sequence of factors for another or c) *adjoin* one sequence of factors to the right (left) of another. A structural condition and set of elementary transformations must meet a condition of compatibility called the *condition of recoverability of deletions* in order to be a transformation. Given a labeled bracketing produced by the base, transformations are applied cyclically to the subsentences of the labeled bracketing beginning with the most deeply embedded sentence, i.e. the subsentence which terminates with the leftmost $]_S$ in the labeled bracketing. In accordance with the principle of the *transformational cycle*, all transformations are applied in order to this subsentence and, after completion of each cycle, the transformations are applied next to the subsentence terminating with the next $]_S$ to the right. This process is iterated until the cycle has operated upon the outermost subsentence. The resulting labeled bracketing is a *surface structure* if it meets a condition of well-formedness, namely that it contain no occurrences of the boundary symbol # . A labeled bracketing φ produced by the base is said to be a *deep structure* underlying the surface structure ψ if φ can be converted by the transformational component into ψ. The pair (φ, ψ) is a *structural description* generated by the grammar and is assigned by the grammar to the sequence of terminal symbols which results from deleting the labeled brackets in ψ. The set of strings of terminal symbols to which the grammar assigns structural descriptions is called the *language generated* by the grammar, and the strings in the language are called sentences.

Notice that not every labeled bracketing produced by the base need be a deep structure. The base rules may introduce the boundary symbol # into a labeled bracketing from which it cannot be deleted in the course of a transformational derivation. The transformational component is said to have filtered out such a labeled bracketing from the set of labeled bracketings produced by the base component. Thus the deep structures are precisely those labeled bracketings produced by the base component which are not filtered out by the transformational component (see Figure 1). Theorem 5.1 of Peters and Ritchie (19) tells us that the class of transformational grammars generates all the recursively enumerable languages. In the proof of this theorem, context-sensitive grammars whose rules did not introduce # were used as base components of the grammars constructed. Thus no use need be made of the filter function of transformations in order to generate all recursively enumerable languages if the base component is allowed to be any context-sensitive grammar. In this paper we investigate the effects of restricting the base component of transformational grammars, heavily exploiting the filter function of transformations. We do not consider here the interesting question whether the theory of transformational grammars would be essentially different if the filter function of transformations were eliminated (i.e. if base rules were not allowed to introduce the boundary symbol).

The major results of Peters and Ritchie (19) concerned the sets of languages generated by certain classes of transformational grammars. In that paper the base component was allowed to be an arbitrary context-sensitive grammar and restrictions were placed on the transformational component, after noting that the full class of transformational grammars generates exactly the recursively enumerable languages. The class of grammars having (total) recursive cycling functions (cf. Definition 6.5 of that paper) was shown to generate exactly the recursive languages. The stronger restriction that a grammar have a cycling function belonging to a certain class (primitive recursive, elementary recursive, etc.) yields grammars which generate only languages with characteristic functions in the same class. We are now able to show, examining the converse question, that each member of these classes of languages is generated by a transformational grammar whose cycling function is in the same class (cf. Theorem 2).

As we turn to restricting the base component, several natural possibilities suggest themselves. We might ask, for example, what class of languages can be generated by transformational grammars with context-free bases, with minimal linear bases or with one-sided linear bases. We might even ask whether a class of transformational grammars having a fixed base component can generate an interesting class of languages. A curiosity of our proofs of the results summarized above was that a single, fixed transformational component sufficed for the generation of all languages in the classes for which we obtained characterizations, each distinct language requiring a different base component in its grammar. While this result does not appear to have any linguistic significance, a parallel question, known as the Universal Base Hypothesis, is of considerable linguistic importance. Some linguists hypothesize that transformational grammars of all natural languages have the same base component. Our results of this paper bear on this hypothesis because they show that restricting the base component, even very stringently, does not restrict the class of languages generated by transformational grammars.

2. Preliminary Results

The fundamental observation from which our results follow is that a sequence of transformations can be used to carry out a computation by an arbitrary Turing machine. This fact is established in Lemma 1, for which it will be convenient to have in mind a specific model of Turing machines. A *Turing machine* Z over the alphabet $A = \{a_1, \ldots, a_n, b\}$ (b is the "*blank*" symbol) is taken as in Davis (1958, pp. 4-7) to be a finite set of quadruples each of which has the form (s_p, c, d, s_q) or (s_p, c, R, s_q) or (s_p, c, L, s_q), where there is a positive integer r (the number of states) such that $1 \leq p, q \leq r$ ($\{s_1, \ldots, s_r\}$ is the set of states and s_1 is the *initial* state), $c, d \in A$ and for every pair (s_p, c), there is at most one quadruple beginning with this pair. The three forms of quadruple mean that when in state s_p scanning c the machine will enter state s_q and either print d, shift right one square, or shift left one square. The Turing machine Z started in state s_1 scanning the leftmost nonblank symbol of byb when $y \in \{a_1, \ldots, a_n\}^*$ goes through a series of steps (one instantaneous description yielding another in the terminology of Davis (1958, p. 7)) and if this sequence reaches a configuration in which no quadruple of Z is applicable, a computation has been performed. The output tape is a sequence, possible the empty sequence, of symbols of $\{a_1, \ldots, a_n\}$ with b's interspersed. The sequence of a_i's which results from the deletion of the b's is denoted Z(y), and we define the language enumerated by Z to be the set of all $x \in A^*$ for which there is a $y \in \{a_1, \ldots, a_n\}^*$ such that $x = Z(y)$.

Our desire is to shift as much as possible of the complexity required to generate arbitrary recursively enumerable languages to the transformational component of grammars so that the base component can be greatly restricted. In Lemma 1 we show that transformations can perform a step-by-step simulation of the computations of an arbitrary Turing machine and, since every recursively enumerable language is enumerated by a Turing machine, the base component need only set up the input tape and thus can be a linear grammar. Lemma 2 establishes that the transformational component can even set up the input tape, if the base component makes a copy of the alphabet available. Theorem 1 combines Lemmas 1 and 2 and shows that as a result the base component can be made extremely simple.

For purely technical purposes it is convenient in the statements of both lemmas to refer to the same special property of labeled bracketings. Because of this property's repeated occurrence and rather lengthy description, we designate it as the "subsentence property" for purposes of reference in this paper. A labeled bracketing φ is said to possess the subsentence property if it has a leftmost subsentence (i.e. a subsentence whose $[_S$ is to the left of all terminal symbols in φ) which either ends with the sequence ####b of terminals and contains exactly one occurrence of b to the left of this string or has as its only terminal symbol a single occurrence of #.

Lemma 1: To every Turing machine Z there is a linear set $\mathcal{B}$ of labeled bracketings and a sequence $\mathcal{T}$ of transformations such that a string x is in the language enumerated by Z if and only if

(1) x does not contain the symbol # and

(2) x is the debracketization of the last line of some transformational derivation with respect to $\mathcal{T}$ having a member of $\mathcal{B}$ as its first line.

In fact, $\mathcal{B}$ and $\mathcal{T}$ may be chosen so that (a) $\mathcal{B}$ is the set of all labeled bracketings of the form

(3) $[_S[_S \cdots [_S[_S[_S \underbrace{\#\ldots\#}_{r} a_1 \ldots a_n b\#\#\#\#b]_S \underbrace{b\ldots b}_{u}\#y\underbrace{b\ldots b}_{v}]_S\#]_S \cdots \#]_S\#]_S$

where r is the number of states of Z, $\{a_1, \ldots, a_n, b\}$ is the alphabet of Z with b being the "blank" symbol, y is an arbitrary nonempty string over $\{a_1, \ldots, a_n\}$, and u and v are positive integers;[1] and (b) every transformation of $\mathcal{T}$ effects the identity mapping on any labeled bracketing such that the subsentence being cycled on does not possess the subsentence property;

and (c) there is a 1-1 association between computations of Z on the one hand and transformational derivations with respect to $\mathfrak{T}$ beginning with a member of $\mathfrak{B}$ and terminating with a #-free bracketing on the other hand such that a computation is associated with a derivation which has the output of the computation as the debracketization of its last line and which involves $k + m + 2$ cycles, where k is the number of steps in the associated computation and m is the length of tape used.

Proof: We begin by showing that the first sentence of the lemma is a consequence of the second. Note that the set of all labeled bracketings of form (3) is a linear set, so that it remains to show that the existence of the 1-1 association asserted as (c) implies that properties (1) and (2) hold of a string x if and only if it is enumerated by Z. But if x is enumerated by Z, then there is a computation of Z with x as output and a transformational derivation associated with the computation as desired. Conversely, if x is #-free and is the debracketization of the last line of a derivation from a string in $\mathfrak{B}$, then the associated computation by Z has x as output so that x is in the language enumerated by Z.

It suffices then to take $\mathfrak{B}$ to be the set of all labeled bracketings of the form (3) and to construct a sequence $\mathfrak{T}$ of transformations satisfying conditions (b) and (c).

The sequence $\mathfrak{T}$ will be constructed so that the computation of Turing machine Z given input y will be mimicked step by step in the transformational derivation with (3) as first line. Simulation of Z on (3) is accomplished by the single transformation T_7.[2] The typical Phrase-marker during the course of the action of transformation T_7 will have the form (4),

(4) $[_S[_S \cdots [_S[_S[_S \underbrace{\#\ldots\#}_{r}\, a_1 \ldots a_n b\underbrace{\#\ldots\#}_{t} b]_S b y_1 \underbrace{\#\ldots\#}_{p} c y_2\, b \;\;]_S\#]_S \cdots \#]_S\#]_S$

where y_1cy_2 is the tape of the Turing machine Z at the step being imitated and Z is in its p^{th} state, s_p, (among its states $s_1, \ldots, s_r$) scanning the symbol c indicated and where t = 4, 5, 6, or 7. In simulating an elementary step by Z, the transformation T_7 must replace $\underbrace{\#\ldots\#}_{p}$ in (4) by $\underbrace{\#\ldots\#}_{q}$ (changing the state from s_p to s_q) and perform the one of the three other operations allowed which is determined by the quadruple of Z in question. A hint of the structural condition and a specification of the elementary transformations of T_7 are

T_7: $[_S \underbrace{\#\ldots\#}_{q} - U_1 - U_2 - U_3 - (\#(\#(\#)))\#\#\#\#b]_S - X - U_4 - e - U_5 - \underbrace{\#\ldots\#}_{p} - e - U_6 - U_7 - U_8 - Y - b -$

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1

substitute 13 for 8

substitute 1 for 10

substitute 9 for 11

substitute 3 for 14

delete 9

delete 13

delete 17

The values of the "dummy variables" U_i are determined by the quadruples of Z. We will employ the following convention in describing the structural condition of T_7: the predicate $i \to i \equiv^{17} x$ (cf Peters and Ritchie, 19 , Definition 2.12) will be abbreviated as $i = x$. The structural condition is the conjunction of the six sentences "$S^{17}_{1\to5}$", "5 = ####b or 5= #####b or 5= ######b or 5= #######b", "8 = e", "11 = e", "16 = b", and "17= #" with a long disjunction containing one disjunct for each quadruple in Z. We now describe how to obtain the disjuncts.

Case I: If the quadruple is a print instruction (s_p, c, d, s_q), then setting $a_{n+1}=b$ and i such that $d=a_i$ the disjunct is "$1 = \underbrace{\#\ldots\#}_{q}$ and $10 = \underbrace{\#\ldots\#}_{p}$ and $2 = \underbrace{\#\ldots\#}_{r-q} a_1 \ldots a_{i-1}$ and $3 = a_i$ and $4 = a_{i+1} \ldots a_{n+1}$ and $14 = c$ and $13 = e$ and $9 = e$ and $12 = e$ and ($7 = a_1$ or ... or $7 = a_n$ or $7 = b$)"; i.e. $U_2 = d$ (the symbol to be printed), $U_8 = c$ (the symbol to be overprinted) and $U_7 = e$, $U_5 = U_6 = e$ and U_4 is one of $a_1, \ldots, a_n$, b.

Case II: If the quadruple is a move right instruction (s_p, c, R, s_q), then the disjunct is "$1 = \underbrace{\#\ldots\#}_{q}$ and $10 = \underbrace{\#\ldots\#}_{p}$ and $13 = c$ and $2 = \underbrace{\#\ldots\#}_{r-q} a_1 \ldots a_{n+1}$ and $3 = e$ and $4 = e$ and $14 = e$ and $9 = e$ and $12 = e$ and ($7 = a_1$ or ... or $7 = a_n$ or $7 = b$)" i.e. $U_7 = c$ (the symbol to be moved right off of) and $U_2 = U_8 = e$, $U_5 = U_6 = e$ and U_4 is one of $a_1, \ldots, a_n$, b.

Case III: If the quadruple is a move left instruction (s_p, c, L, s_q), then the disjunct is "$1 = \underbrace{\#\ldots\#}_{q}$ and $10 = \underbrace{\#\ldots\#}_{p}$ and $12 = c$ and ($9 = a_1$ or ... or $9 = a_n$ or $9 = b$) and $2 = \underbrace{\#\ldots\#}_{r-q} a_1 \ldots a_{n+1}$ and $3 = e$ and $4 = e$ and $14 = e$ and $13 = e$ and $7 = e$"; i.e. $U_6 = c$ (the symbol to be moved left off of) and U_5 is one of $a_1, \ldots, a_n$, b and $U_2 = U_8 = e$, $U_7 = e$ and $U_4 = e$.

In deciphering T_7, it may be helpful to notice that U_6, U_7 and U_8 are respectively the scanned square in simulating moves of the types "left", "right" and "print" and that U_4 is present to assure both that the sequence of p #'s in term 11 is not a proper substring of the string representing the state of Z (hence the state of Z really is s_p) and also that no move is made if the leftmost b of the tape is under scan.

Term 16 simply guarantees that no move is made if the rightmost b of the tape is being scanned, term 17 with its associated deletion elementary transformation accomplishes the erasure of the new boundary symbol which appears as each cycle is taken in the transformational derivation and terms 1 and 10 accomplish the state change. A print instruction is accomplished by the replacement of term 14 (U_8) by term 3 (U'_2), a move right instruction by the replacement of term 8 (e) by 13 (U'_7) and a move left instruction by the replacement of term 11 (e) by term 9 (U'_5).

It is straightforward to check that T_7 imitates Z when applied to Phrase-markers such as (4), except in the moves labeled (3) and (5) by Davis (1958, p. 7), which add new tape squares if the edge of the tape is reached. If the end of the input tape as set up in (3) is reached, the structural condition of T_7 is not satisfied and the reader can easily check that it and each of the transformations T_5, T_C, T_8, T_9 and T_{10} defined below apply vacuously on all remaining cycles so that the Phrase-marker produced contains #'s. We now introduce T_5 and T_6 which utilize the value of t in labeled bracketings of the form (4) to record whether or not Z's computation uses all the tape provided except the leftmost and rightmost squares. The value of t, initially 4, is increased by 1 when the leftmost usable square of tape is reached for the first time (T_5) and by 2 when the rightmost usable square is reached for the first time (T_6), so that t equals 7 just in case both ends but for one square have been reached.

$$T_5:\ [_S \underbrace{\#\ldots\#}_{r}\, a_1 \ldots a_n b\#\#\# - \# - (\#\#)b]_S - b\# - Y - \#$$

$$\begin{array}{llllll} 1 & 2 & 3 & 4 & 5 & 6 \\ 1+2 & 2 & 3 & 4 & 5 & 6 \end{array}$$

$$T_6:\ [_S \underbrace{\#\ldots\#}_{r}\, a_1 \ldots a_n b\#\# - \#\# - (\#)b]_S - Y - \# \left\{\begin{array}{c} a_1 \\ \vdots \\ a_n \\ b \end{array}\right\} b\#$$

$$\begin{array}{lllll} 1 & 2 & 3 & 4 & 5 \\ 1+2 & 2 & 3 & 4 & 5 \end{array}$$

When a configuration of form (4) is reached representing an instantaneous description of Z in which Z halts and in which all the tape provided has been used, then the clean-up transformations T_8, T_9, and T_{10} become applicable. Transformation T_8, which will not apply on any cycle on which T_7 has applied (non vacuously) since T_8 requires # as rightmost symbol and T_7 deletes the rightmost #, checks that the squares at each end of the tape are not being scanned--guaranteeing that the inapplicability of T_7 was not occasioned by Z's running off the edge of the tape--and also checks that $t=7$, insuring that no excess tape was provided. If these conditions are met, then T_8 erases the b in the right end square and the sequence of #'s representing the state in which Z halted, replaces the deepest subsentence by #, and positions a single # on the tape to signal applicability of T_9. T_9 passes a # across the tape from left to right, one square at a time erasing each b encountered. After T_9 has passed the # across all of the tape but the rightmost symbol, T_{10} erases this # (and the rightmost symbol if it is b), leaving exactly the string on $a_1, \ldots, a_n$ output by Z.

$$T_8\colon\ [_S \underbrace{\#\ldots\#}_{r} a_1 \ldots a_n b \#\#\#\#\#\# - \# - b]_S - X - \left\{\begin{matrix} a_1 \\ \vdots \\ a_n \\ b \end{matrix}\right\} - \underbrace{\#\ldots\#}_{1 \le j \le r} - \left\{\begin{matrix} a_1 \\ \vdots \\ a_r \\ b \end{matrix}\right\} - Y - b\#$$

1 2 3 4 5 6 7 8 9

0 2 0 2+4 5 0 7 8 0

$$T_9\colon\ [_S \#]_S - X - \# - \left\{\begin{matrix} b \\ e \end{matrix}\right\} - \left\{\begin{matrix} e \\ a_1 \\ \vdots \\ a_n \end{matrix}\right\} - Y - \#$$

1 2 3 4 5 6 7

1 2 0 0 5+3 6 0

Condition $6 \neq e$.

$$T_{10}\colon\ [_S \#]_S - X - \# - \left\{\begin{matrix} b \\ e \end{matrix}\right\} - \left\{\begin{matrix} e \\ a_1 \\ \vdots \\ a_n \end{matrix}\right\} - \#$$

1 2 3 4 5 6

0 2 0 0 5 0

Returning to the statement of Lemma 1, we recall that we have taken $\mathfrak{B}$ to be the set of labeled bracketings of the form (3) as promised in (a). We now take $\mathfrak{T}$ to be the sequence $(T_5, T_6, T_7, T_8, T_9, T_{10})$ of transformations just constructed, note that (b) is satisfied and complete the proof by showing that (c) also holds.

Note first that to every labeled bracketing φ in $\mathfrak{B}$ there is a unique transformational derivation with respect to $\mathfrak{T}$ having φ as its first line. We now associate with each computation by Z the unique derivation with respect to $\mathfrak{T}$ beginning with the labeled bracketing φ of the form (3) in which

(i) y is the input beginning the computation by Z

(ii) u and v are respectively the number of squares to the left and right of the input y used in this computation, and

(iii) there are exactly $k + u + v + \ell(y) + 2$ subsentences of φ where k is the number of steps in the computation and where $\ell(y)$ is the length of y.

Note that, by the construction of $\mathfrak{T}$, this derivation will have a #-free last line, since T_8 will apply nonvacuously on the k+3rd cycle and exactly m-1 cycles later T_{10} will apply deleting the final #'s, where $m = u+v+\ell(y)$; further the debracketization of this last line is just the output of the computation. We must now show the converse to establish the 1-1 association asserted to exist in part (c) of the lemma; namely that to each derivation which begins on a φ of the form (3) and which has its last line #-free there is an associated computation by Z such that (i), (ii), and (iii) hold. To show this, observe that the last line of the derivation begun on any φ of the form (3) is #-free if and only if T_{10} applied nonvacuously on the final cycle; for each member of $\mathfrak{B}$ contains a # and the existence of the #'s is preserved by $T_5, \ldots, T_9$. But this happens if and only if T_8 applied nonvacuously m-1 cycles earlier. Further, T_8 applies nonvacuously if and only if there is a preceding sequence of some number, k, of cycles, beginning with the 3rd cycle of the derivation, in which T_7 imitated step by step the unique sequence of steps by Z begun on input y and this sequence is an imitation of a computation by Z satisfying (i) and (ii). The number of subsentences is exactly $k + m + 2$ as desired, since after two initial vacuous cycles k cycles imitating the computation precede the nonvacuous application of T_8 and m-1 cycles follow it, hence part (c) of the lemma is proved and the lemma has been established.

The necessity of generating the labeled bracketings of $\mathcal{B}$ does not require much complexity of the base component. But the role of this component can be reduced even further since the transformations can be made to setup the "input tape", as well as carry out a "computation" on it. We demonstrate this in Lemma 2.

Lemma 2: There is a minimal linear set $\mathcal{B}'$ of labeled bracketings and a sequence $\mathcal{T}'$ of transformations such that every labeled bracketing of the form (3) is the last line of a transformational derivation whose first line is in $\mathcal{B}'$ and further, every bracketing which is the last line of such a derivation that is not of the form (3) contains at least one # and also fails to possess the subsentence property. In fact, $\mathcal{B}'$ and $\mathcal{T}'$ may be chosen so that (a) $\mathcal{B}'$ is the set of all labeled bracketings of the form (5),

(5) $[_S[_S \cdots [_S[_S a_1 a_2 \cdots a_n b\#]_S\#]_S \cdots \#]_S\#]_S$

(b) every transformation in $\mathcal{T}'$ effects the identity mapping on each labeled bracketing which possesses the subsentence property; and (c) in every transformational derivation from a labeled bracketing of type (5) to a labeled bracketing of the form (3), at least one transformation in $\mathcal{T}'$ applies nonvacuously on each of the first $m+1$ cycles, where $m= u+v+\ell(y)$.

Proof: We take $\mathcal{B}'$ to be the set of strings of form (5) and construct the four transformations which constitute $\mathcal{T}'$. Transformation T_1 produces the r boundaries for the innermost subsentence and T_2 positions them correctly, and adds a b as rightmost symbol. Both apply nonvacuously only on the first cycle of a derivation.

$$T_1:\quad a_1 \ldots a_n - e - \ldots - e - b - \#$$

$$\begin{array}{ccccc} 1 & 2 & r+1 & r+2 & r+3 \\ 1 & r+3 & r+3 & r+2 & r+3 \end{array}$$

$$T_2:\quad a_1 \ldots a_n - \underbrace{\# \ldots \#}_{r} - b - \#$$

$$\begin{array}{cccc} 1 & 2 & 3 & 4 \\ 2+1 & 0 & 3 & 4+3 \end{array}$$

Transformations T_3 and T_4 produce the other three #'s in the innermost subsentence and the string $b^u\#yb^v$.

$$T_3:\quad [_S\, \underbrace{\#-\#\ldots}_{r-1}\#a_1 \ldots a_n - b - \left\{\begin{matrix} e & - & \# \\ \# & & e \end{matrix}\right\} - (\#\#)\, b]_S - X - \#$$

$$\begin{array}{cccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 2 & 3 & 4 & 4+5 & \text{[illegible]} & 3+7 & 0 \end{array}$$

Condition: 1 is not an S.

$$T_4:\quad [_S\, \underbrace{\#-\#\ldots}_{r-1}\#a_1 \ldots a_{i-1} - \underset{1\leq i\leq n}{a_i} - a_{i+1} \ldots a_n\, b - \left\{\begin{matrix} e & - & \# \\ \# & & e \end{matrix}\right\} \#b]_S - e - X - \#$$

$$\begin{array}{ccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\ 1 & 2 & 3 & 4 & 5 & 5+6 & \text{[illegible]} & 3+8 & 0 \end{array}$$

Condition: 1 is not an S.

On the second cycle and an arbitrary number of following cycles, T_3 will apply producing the string b^v in v cycles. On all but the last of these cycles, the fourth factor of proper analyses for T_3 will be the empty string. As soon as the fourth factor is taken as #, a second boundary is added in the innermost subsentence and T_3 becomes temporarily inapplicable. Transformation T_4 is applicable as long as the innermost subsentence contains two #'s at its right and applies on the v+2nd and following cycles until term 5 of its proper analysis is taken as #. At this point a third # is added to the innermost subsentence, the string #y has been positioned to the left of b^v and T_3 once again becomes applicable. Transformation T_3 can produce b^u and add the fourth # in the innermost subsentence in u more cycles. Thus if φ is any labeled bracketing of the type (3) then, letting s be the number of subsentences of φ, there is clearly a transformational derivation begun on the labeled bracketing of the type (5) with exactly m+s-1 subsentences, such that φ is the last line of the derivation, and nonvacuous applications of transformations occur on exactly the first m+1 cycles, establishing property (c). That $\mathcal{G}'$ satisfies (b) is immediate by inspection of $T_1, \ldots, T_4$. Finally, notice that every line in every derivation contains at least one # and fails to satisfy the subsentence property until an application of T_3 is made to a labeled bracketing in which the leftmost subsentence ends in ###b and in which term 4 of its proper analysis is #. Since this results in a string of form (3), we see that if the last line of a derivation possesses the subsentence property, then it is also a line of form (3) as desired, completing the proof.

3. Restricted Bases

We now have the tools to attack the questions we have raised regarding restrictions on the base component. Our first result exhibits a highly restricted base component which is universal in the sense that every language that can be generated by a transformational grammar is generated by a grammar with this particular, fixed base component. This theorem also establishes the result announced as Theorem 5.2 in Peters and Ritchie (19).

Theorem 1: The following five conditions are equivalent:

(i) L is a recursively enumerable language over the alphabet $\{a_1, \ldots, a_n\}$

(ii) L is generated by a context-free based transformational grammar

(iii) L is generated by a minimal linear based transformational grammar

(iv) L is generated by a one-sided linear based transformational grammar

(v) L is generated by a transformational grammar with the base component having rules $S \rightarrow S\#$, $S \rightarrow a_1 \ldots a_n b\#$, where b and # are terminal symbols not in $\{a_1, \ldots, a_n\}$, # being the boundary symbol.

Proof: It is clear that (v) implies each of (iii) and (iv) and that they each imply (ii). That (ii) implies (i) follows *a fortiori* from Theorem 5.1 of Peters and Ritchie (19). It remains only to show that (i) implies (v) to complete the proof, so let us assume that L is an r.e. language and construct a transformational grammar generating L with base component as in (v). Since L is r.e., there is a Turing machine Z enumerating L. Let $\mathcal{B}$ be the set of all labeled bracketings of the form (3) and let $\mathcal{T}$ be the sequence of transformations guaranteed by Lemma 1 to derive L from $\mathcal{B}$. Further, let $\mathcal{H}$ be the sequence of transformations given by Lemma 2 which produces all the labeled bracketings of the form (3) from those of the form (5), i.e. from those strongly generated by the base component $S \rightarrow S\#$, $S \rightarrow a_1 \ldots a_n b\#$. We shall show that the transformational grammar with this base and with transformational component $\mathcal{T}''$ consisting of the transformations of $\mathcal{T}'$ followed by those of $\mathcal{T}$ generates exactly L. Let x be any element of L and let Z generate x from an input string y with a computation involving k steps, u squares to the left of y and v squares to the right. The transformational grammar generates x as follows. The base component produces the bracketing of the form (5) with exactly k+2m+1 subsentences where m is the sum of u,v and the length of y. By Lemma 2, the sequence $\mathcal{T}'$ of transformations can produce from this the labeled bracketing of the form (3) with k+m subsentences surrounding

$$[_S[_S \underbrace{\#\ldots\#}_{r} a_1\ldots a_n b\#\#\#\#b]_S \underbrace{b\ldots b}_{u}\#y\underbrace{b\ldots b}_{v}]_S$$

But then so can $\mathcal{T}''$ since at each of the first m+1 cycles in this derivation, the subsentence property cannot be possessed by the labeled bracketing acted upon (or else the derivation by $\mathcal{T}'$ would not continue, by Lemma 2 (b)) so that each transformation in $\mathcal{T}$ effects the identity mapping, by Lemma 1 (b). But then $\mathcal{T}$ applied to this labeled bracketing yields a #-free string whose debracketization is x, by Lemma 1 (c), and $\mathcal{T}''$ acts in exactly the same fashion since now the subsentence property is possessed by each line (by Lemma 1 (b)) so that each transformation in $\mathcal{T}'$ acts vacuously at each of these steps, by Lemma 2 (b). Hence every string in L is generated by the transformational grammar. For the converse, consider an arbitrary derivation by $\mathcal{T}''$ from any labeled bracketing of the form (5). Since any string in (5) fails to possess the subsentence property, the derivation is identical to one by $\mathcal{T}'$ until either a labeled bracketing is produced which possesses the subsentence property or the derivation terminates. By Lemma 2 the labeled bracketing φ produced at this point is either of form (3) or else fails to possess the subsentence property. If φ has form (3), then the derivation continues identically with the derivation from φ by $\mathcal{T}$ and thus concludes with a #-free labeled bracketing only if its debracketization is an element of L by Lemma 1. On the other hand, if φ is not of form (3), then the derivation in a string which contains a #, hence is not a surface structure. Thus the only sentences generated are in L.

Thus if transformational components of grammars are allowed to vary freely, then restricting base components to contain only context-free rules, only left-linear rules or only right-linear[3] rules does not diminish the set of languages that can be generated. Transformations are such powerful devices that they can map highly restricted sets generated by very impoverished base components into arbitrary recursively enumerable languages. In fact transformations are so powerful they can generate any recursively enumerable language from certain fixed sets of Phrase-markers, the outputs of certain particular grammars. Such universal base components are highly nonunique; some are trivial - as in Theorem 1 (v) - and some are very complex.

One infinite class of universal base components contains all linear grammars satisfying three conditions: a) every Phrase-marker generated contains at least one occurrence of the boundary symbol #, b) for every positive integer n a Phrase-marker is generated containing at least n subsentences and c) all symbols of the alphabet over which recursively enumerable languages are to be generated appear in each member of a set of Phrase-markers satisfying b) in such a way that the same structural condition can be used to identify them in each subsentence of every member of this set. The grammar of Theorem 1 (v) is a member of this class. While none of these grammars is linguistically natural, there are infinitely many universal base components which are not in this class. Grammars proposed by Anderson, Ross and Lakoff as universal base components suffice for the generation of every recursively enumerable language. It is likely, therefore, that every natural language can be generated from each of them (cf. Peters and Ritchie, 19 ,97). This fact points up the difficulty in empirically supporting or disconfirming the claim that all natural languages have the same base structure.

Turning now to a consideration of the transformational component one should note that the number of transformations in the grammar of the proof of Theorem 1 is of no particular significance. With minor alterations the ten transformations used in the proof can be collapsed to one. Clarity of presentation was the sole motive for using more. It is worth remarking that even with a fixed base component all recursively enumerable languages can be generated with very little variability in the transformational component of grammars. Only T_7

above depends in any essential way on the particular language to be generated. By changing the set-up part of the grammar, we can have T_7 simulate a fixed universal Turing machine and all the variability in the grammar can be confined to specifying the exact value of one constant term in the structural condition of one transformation. Thus the base and the transformational components can simultaneously be made universal in this way.

From the standpoint of empirical adequacy, a grammar must do more than simply generate the right strings as sentences. It must also, for example, assign the correct number of structural descriptions (degree of ambiguity) to each sentence. Transformational grammars have a remarkable flexibility in this regard also.

Remark: For any alphabet A, there is a one-sided linear grammar B with the following property. Given any recursively enumerable language L over A and any recursive function f into $\{1, 2, 3, \ldots\} \cup \{\aleph_0\}$ with $L \subseteq$[4] Domain (f), there is a transformational grammar which has base component B, which generates L and which assigns every string x in L exactly $f(x)$ structural descriptions.

Since L is recursively enumerable, it is the range of some 1-1 recursive function g from the natural numbers into A^*. Thus there is a recursive function h the value of which is (a) $g(n)$ on $2^m 3^n$ if $1 \leq m \leq f(g(n))$ and (b) undefined on every other argument. The function h has the same range as g and maps onto a string x exactly $f(x)$ inputs. Taking Z as a Turing machine which computes h, we obtain the desired grammar by Lemma 1, since for each labeled bracketing in $\mathcal{B}$ there is exactly one transformational derivation with respect to $\mathcal{J}$. An immediate consequence is that every recursively enumerable language has an unambiguous transformational grammar. Clearly the other empirical constraints on grammars deserve similar study.

4. Transformational Grammars With Bounded Cycling

Let us conclude with some results about the effect of restricting the cycling function $f_{\mathcal{J}}$ of a transformational grammar $\mathcal{J}$. Recall that if x is in L ($\mathcal{J}$), then $f_{\mathcal{J}}$ (x) is the smallest number s such that some deep Phrase-marker underlying x has exactly s subsentences, and $f_{\mathcal{J}}$ (x) = 0 if x is not in L ($\mathcal{J}$). In Corollary 6.7 of Peters and Ritchie (19) we showed that if $f_{\mathcal{J}}$ was bounded by a function which is elementary recursive (or primitive recursive, or in any one of Grzegorczyk's classes $\mathcal{E}^n$), then L ($\mathcal{J}$) is an elementary recursive language (primitive recursive language, language in $\mathcal{E}^n$), but we left open the converse. In Corollary 6.6 we showed that $f_{\mathcal{J}}$ was bounded by a recursive function if and only if L ($\mathcal{J}$) was recursive, but noted that the proof did not extend to subrecursive classes. Since the class of elementary recursive functions was shown to be equivalent to the class of "predictably computable" functions in Ritchie (1963), the converse question has a natural interpretation; namely, it excludes the existence of languages in which decisions of grammaticality can be made predictably, but in which these decisions can not be reached by recreating the deep structure, which has unpredictably deep nesting of subsentences. We now prove two theorems which show that for every elementary recursive language, there is a grammar with elementary recursive cycling function (hence predictable deep structures), and also another grammar in which the cycling function is arbitrarily large (and hence the deep structure has unpredictably deep nesting).

Theorem 2: The following three conditions are equivalent for any language L:

(i) L is elementary recursive

(ii) there exists a transformational grammar $\mathcal{G}$ such that
$L = L(\mathcal{G})$ and $f_{\mathcal{G}}$ is elementary recursive

(iii) there exists a transformational grammar $\mathcal{G}$ such that
$L = L(\mathcal{G})$ and $f_{\mathcal{G}}$ is pointwise bounded by an elementary recursive function.

The same holds if elementary recursive is replaced by primitive recursive or $\mathcal{E}^n$ for any $n \geq 3$, where $\mathcal{E}^n$ is defined in Grzegorczyk (1953).

Proof: We shall show the theorem for the elementary recursive case; the other cases being entirely similar. That (ii) implies (iii) is trivial since any elementary recursive function bounds itself. That

(iii) implies (i) is proved in Corollary 6.7 of Peters-Ritchie (1969). Thus we need only show that (i) implies (ii), and to do so let us now assume that L is an elementary recursive set, i.e. that the characteristic function χ_L of L is elementary recursive, where $\chi_L(x) = 1$ if $x \in L$ and $\chi_L(x) = 0$ otherwise. If L is empty, the result is trivial, so assume that L is nonempty and that $x_o \in L$. Let f be the elementary function that enumerates L as follows: on input x, $f(x) = x_o$ if $x \notin L$, while $f(x) = x$ if $x \in L$. (To see that f is elementary recursive, one might define f formally as $f(x) = x \cdot \chi_L(x) + x_o \cdot (1 \dot{-} \chi_L(x))$ and appeal to the known closure properties of the elementary recursive functions as established in Grzegorczyk (1953).) Let Z be a Turing machine which computes f predictably, and let $\mathcal{G}$ be the transformational grammar for Z given by Lemma 1. Since Z computes predictably, the m and k given in part (c) of the lemma are elementary recursive functions of x (see Ritchie (1963) and Cobham (1965)). Thus $f_{\mathcal{G}}(x)$, which is in this case just k+m+2, is elementary recursive, completing the proof.

This theorem contrasts with Corollary 6.7 of Peters and Ritchie (19), which showed that in the case of the class of all recursive functions, the three conditions

(i) $L(\mathcal{G})$ is recursive

(ii) $f_{\mathcal{G}}$ is recursive, and

(iii) $f_{\mathcal{G}}$ is pointwise bounded by a recursive function

were equivalent for *each* transformational *grammar*. Theorem 2 only asserts for the language L that elementary recursiveness is equivalent to the existence of at least one grammar $\mathcal{G}$ for L with appropriate $f_{\mathcal{G}}$. Theorem 3 shows that it is impossible to strengthen this result so that it becomes a statement about all grammars generating an elementary recursive set.

Theorem 3: To every elementary recursive set L, there is a transformational grammar $\mathcal{G}$ such that $L = L(\mathcal{G})$ and $f_{\mathcal{G}}$ is not bounded by any elementary recursive function. In fact, to every r.e. set L (including very simple r.e. sets, for example regular sets), and to every recursive function f(x) (no matter how complex and rapidly growing, for example Ackermann's function(Ritchie, 1963, p. 272)), there is a transformational grammar $\mathcal{G}$ such that $L = L(\mathcal{G})$ and $f_{\mathcal{G}}(x) \geq f(x)$ for all x in L.

Proof: The first assertion of this theorem follows from the second since, for example, any function g such that $g(x) \geq f(x)$ for all x, where f(x) is Ackermann's function, is not primitive recursive (Ritchie, 1963, p. 272),hence certainly not elementary. To prove the second assertion, let L and f be given, and let Z be the Turing machine which enumerates L as follows. Let h be a recursive function having as range the r.e. set L. On input y compute h(y) and $p^{f(h(y))+1}$ where p is the cardinality of Z' alphabet. Then erase the number $p^{f(h(y))+1}$ preserving the output f(x) and halt. Lemma 1 produces a transformational grammar generating L for which the value of the cycling function is greater at each element $x = h(y)$ of L than the number of steps taken by Z in the computation described above. But this involves more than $f(x)$ steps (since $p^{f(x)+1}$ occupies at least $f(x)+1$ squares of tape and hence its erasure requires more than $f(x)$ steps), so $f_{\mu_j}(x)>f(x)$ as desired.

Notes

[1] The contents of the innermost subsentence of (3) are present for technical convenience, and the # to the left of y signals that Z is scanning the leftmost symbol of y in initial state s_I. Labeled bracketings of the form (3) will underlie a #-free Phrase-marker only if u and v are the numbers of tape squares to the left and right respectively of the input y used by Z in its computation. These points will be clarified in the subsequent discussion of the transformational rules.

[2] The first transformation in $\mathcal{T}$ which we discuss is called T_7 because six transformations will eventually precede it; two will be discussed soon and four others will not be introduced until Lemma 2.

[3] Clearly the reflections of all recursively enumerable languages can be generated by grammars with a fixed right-linear base component and appropriate transformational components (simply reverse all base and transformational rules discussed in the proof of Theorem 1). But this is sufficient, since the set of recursively enumerable languages is closed under the operation of reflection.

[4] One may interpret the strings of A^* as p-adic representations of natural numbers, where p is the cardinality of A. To avoid any aura of mysticism here about f taking $\aleph_0$ as a value, note that we may replace $\aleph_0$ in the remark by 0 if we modify the natural ordering $\leq$ just so that $n \leq 0$ for any natural number n.

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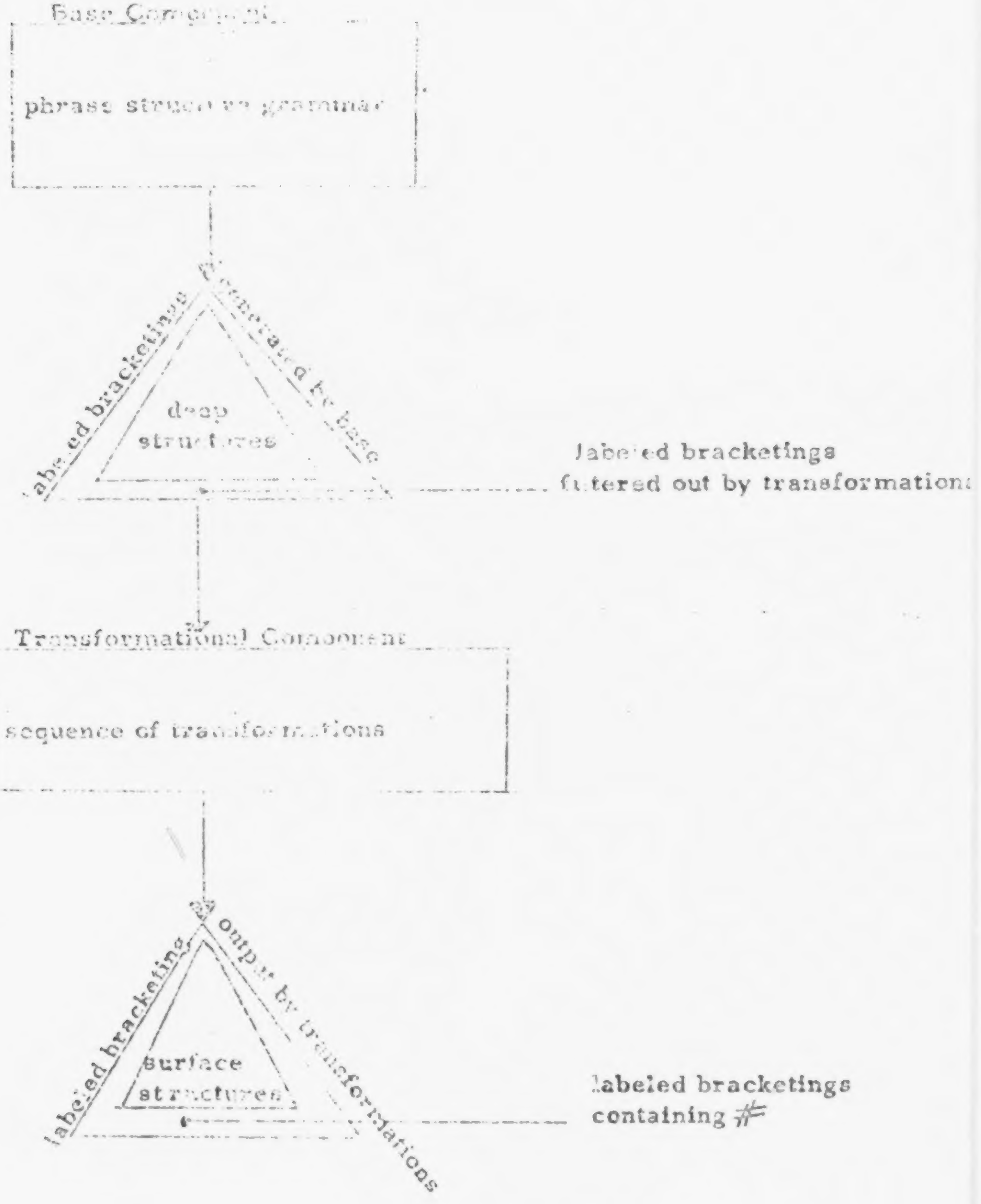
Figure 1 of


Base Component
phrase structure grammar
labeled bracketings generated by base
deep structures
labeled bracketings filtered out by transformations
Transformational Component
sequence of transformations
labeled bracketing output by transformations
surface structures
labeled bracketings containing #

Comments on Montague's Paper

by

Patrick Suppes

Workshop on Grammar and Semantics
of Natural Languages

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11/20/70

Comments on Montague's Paper

Because Montague's efforts at analyzing the semantics and syntax of natural language have probably been developed more extensively than any other now available, it is natural to raise some questions, not so much about the paper itself but about his own perspective on the future of the kind of analysis he has given us. I raise these questions partly because they have puzzled me about my own work, which seems to have a somewhat different objective than his.

Let me begin with a very general question about the empirical character of his analysis. From listening to the present paper and reading some related papers by Montague (1970, 1971) it is not clear to me whether Montague regards the problem of providing a semantics and syntax of natural language as an empirical problem. Since this question is at the heart of my remarks, let me try to expand upon it. In asking if the analysis of formal language in his sense is meant to be an empirical matter, I do not have in mind some subtle and obscure distinction between empirical and logical inquiries. I have in mind a rather crude distinction, one that we cannot always apply but one that we recognize in many applications. The kind of distinction I have in mind is, for example, the distinction between ancient geometry as set forth by Euclid and ancient astronomy as set forth by Ptolemy. In one clear sense, it seems to me, Euclid aims to be mathematical and not empirical, and Ptolemy aims to be empirical, although of course he uses in an extraordinarily successful way mathematical methods. For Euclid the criterion of success is primarily the proofs of theorems; for Ptolemy it is fundamentally the fit of theory to data.

My first question to Montague is this. Does he feel a closer affinity to the methods and implicit criteria of Euclid or of Ptolemy?

I would like to go on to assume, for additional remarks, that he will accept as appropriate for his kind of enterprise neo-Ptolemaic questions about the fit of theory to data, and I would like to set forth several theses, some of which I am rather certain he will reject and others that he will probably accept. What I am asking of him is clarification about how he stands on these theses, and I won't reveal my own guesses as to what I think his answers will be.

Thesis 1. The Montague semantics and syntax of ordinary English as set forth in the current paper and in Montague (1970, 1971) can be extended by a reasonably small number of additional rules, including additional basic sets of expressions, etc., and with this extension, substantial texts or substantial corpuses of spoken speech can be analyzed. In this formulation it is understood that, although the general sort of text might be known in advance, the text itself is not looked at in setting forth the full set of rules, etc. In other words, a machinery of analysis is set up that can be applied without change to any of a wide variety of texts.

In this connection, I cannot resist asking a probabilistic sort of question. In terms of my own approach to these matters I would want to introduce generative probabilities into Montague's rules so that an estimate could be given of the goodness of fit of the model of the theory to the data of the text. I am not at all certain that Montague would want to accept this kind of approach. I ask him what kind of criterion of goodness of fit he would want to use.

Thesis 2. The weaker thesis is that the text or corpus must be examined in order to specify the new basic sets of expressions, some new syntactic rules, some new rules of functional application, and so forth, but that relative to a very large corpus, for example, one of a million utterances, a relatively small number of additional rules can be added in order to provide an analysis of the text. My own work on probabilistic grammars (1970) falls under this weaker thesis. The grammars were not written without examining the corpus, and the probabilistic parameters were written only by analyzing the corpus. The scientific respectability of the enterprise was preserved as in other such application of probabilistic models, by the relatively small number of parameters estimated from the data in relation to the number of utterances considered. Again, however, I am not at all certain that Montague would be satisfied with such a probabilistic criterion.

Criterion of successful analysis. In connection with everything that I have said thus far, I also am not clear what he would regard as a way of stating the methodology of analyzing a given sentence in natural language in the sense of how agreement is to be got that the semantic analysis is the correct one. I must say that I am dissatisfied with my own methodology as reflected in my own paper on this matter. I feel relatively happy with the objectivity of the grammatical analysis. I do not feel nearly as satisfied with the objectivity of the semantic analysis. It seems to me that my analysis of the semantics of Adam I, whatever its other defects, certainly suffers from the defect of depending upon my own rough and ready intuitions about what Adam meant to say in uttering the phrases he did. It does not seem to me that in my own work I have specified at all a really good criterion for making objective the semantic analysis. In stating the above theses I have talked about the analysis of sentences or of utterances but again I have left deliberately vague spelling out what is to be regarded as an analysis. I have in mind here of course not the kind of model that Montague stated but whether the criterion for deciding whether or not the model has correctly accounted for the structure of a given sentence. How does he feel about this problem of evaluation?

Possible evidence against Montague's theory. The problem of making objective the criterion is related to the problem of trying to get a clear sense of what evidence Montague would count as proving his conception of the proper way to analyze the semantics and syntax of natural language is wrong. Of course, this question is not one that is meant to have a simple answer. In my own work I would distinguish between giving evidence to refute the general theory and evidence that counts against a particular model with particular probabilistic parameters. In the latter case the characterization of evidence that can count decisively or strongly against the correctness of a particular model is easy to give. The corresponding problem for the general theory is more difficult. It would be interesting to hear how Montague feels about this standard and ubiquitous problem for the case of his own theory.

Machine language translation. Most linguists and computer scientists are discouraged about the prospects for mechanical language translation in any immediate future. A good many people feel that the early overly sanguine and optimistic predictions and claims in this field fell through precisely because of the absence of any serious theoretical underpinnings for the premature attempts that were made. Although Montague as far as I know has indicated no special interest in problems of mechanical language translation, because of the extensive technical analysis of fragments of natural language he has given us, it is natural to ask him to express his views on the problems and prospects of machine translation, and I suppose my real point in asking him for his views is my feeling that his answer will provide a further perspective on the extent to which he views his theoretical analyses as empirical or quasi-empirical in character.

Semantics of Context-free Fragments of Natural Languages

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1. Introduction

The search for a rigorous and explicit semantics of any significant portion of a natural language is now intensive and far-flung--far-flung in the sense that wide varieties of approaches are being taken. Yet it is agreed by almost everyone that at the present time the semantics of natural languages are less satisfactorily formulated than the grammars, even though a complete grammar for any significant fragment of natural language is yet to be written.

A line of thought especially popular in the last couple of years is expressed in the idea that the semantics of a natural language can be reduced to the semantics of first-order logic. One way of fitting this scheme into the general approach of generative grammars is to think of the deep structure as being essentially identical with the structure of first-order logic. The central difficulty with this approach is that now as before it is still unclear how the semantics of the surface grammar is to be formulated. In other words, how are explicit formal relations to be established between first-order logic and the structure of natural languages? Without the outlines of a formal theory, this line of approach has moved no further than the classical stance of introductory teaching in logic, which for many years has concentrated on the translation of English sentences into first-order logical notation. The method of translation, of course, is left at an intuitive and ill-defined level.

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The strength of the first-order logic approach is that it represents essentially the only semantical theory with any systematic or deep development, namely, model-theoretic semantics as developed in mathematical logic since the early 1930's, especially since the appearance of Tarski (1935). The semantical approaches developed by linguists or others whose viewpoint is that of generative grammar have been lacking in the formal precision and depth of model-theoretic semantics. Indeed, some of the most important and significant results in the foundations of mathematics belong to the general theory of models. I shall not attempt here to review the approaches to semantics that start from a generative-grammar viewpoint, but I have in mind the work of Fodor, Katz, Lakoff, McCawley and others.

The objective of the present paper is to combine the viewpoint of model-theoretic semantics and generative grammar, to define semantics for context-free languages, and to apply the results to some fragments of natural language, especially to the corpus of speech of a young child. The ideas contained in the present article were developed while I was working with Helene Bestougeff on the semantical theory of question-answering systems. Later some earlier similar work by Knuth (1969) came to my attention. The developments here are rather different from those of Knuth, especially because my objective is to provide tools for the analysis of fragments of natural language, whereas Knuth is concerned with programming languages.

Although on the surface the viewpoint seems different, I have also benefited from a study of Montague's interesting and important work (1969) on the analysis of English as a formal language. My purely extensional line of attack is simpler than Montague's. I have adopted it for reasons of expediency, not correctness. I wanted an apparatus that could be applied in a fairly direct way to empirical analysis of a corpus. I have begun, as in my work on probabilistic grammars (Suppes 1970), with the speech of a young child, but without doubt, many of the semantical problems that are the center of Montague's concern will need to be dealt with in analyzing slightly more complex speech. Indeed, some of them already arise in the corpus studied here. As in the case of my earlier work on probabilistic grammars, I have found a full-scale analytic attack on a corpus of speech a humbling and bedeviling experience. The results reported here hopefully chart one possible course, in no sense are they more than preliminary.

This paper is organized in the following fashion. In Section 2, I describe a simple artificial example to illustrate how a semantic valuation function is added to the generative mechanisms of a context-free grammar. The relevant formal definitions are given in Section 3. The reader who wants a quick survey of what can be done with the methods, but who is not really interested in formal matters, can skip ahead to Section 4, which contains the detailed empirical results. On the other hand, it will probably be somewhat difficult to comprehend fully the machinery used in the empirical analysis without some perusal of Section 3, unless the reader is already quite familiar with model-theoretic semantics.

2. A Simple Example

To illustrate the semantic methods described formally below, I shall use as an example the same simple language I used in Suppes (1970). As remarked there, this example is not meant to be complex enough to fit any actual corpus; its context-free grammar can easily be rewritten as a regular grammar. The five syntactic categories are V_1, V_2, Adj, PN and N, where V_1 is the class of intransitive verbs, V_2 the class of transitive verbs or two-place predicates, Adj the class of adjectives, PN the class of proper nouns and N the class of common nouns. Additional nonterminal vocabulary consists of the symbols S, NP, VP and AdjP. The set P of production rules consists of the following seven rules, plus the rewrite rules for terminal vocabulary belonging to one of the five categories.

Production Rule	Semantic Function
1. $S \rightarrow NP + VP$	Truth-function
2. $VP \rightarrow V_1$	Identity
3. $VP \rightarrow V_2 + NP$	Image of the converse relation
4. $NP \rightarrow PN$	Identity
5. $NP \rightarrow AdjP + N$	Intersection
6. $AdjP \rightarrow AdjP + Adj$	Intersection
7. $AdjP \rightarrow Adj$	Identity

If Adj^n is understood to denote a string of n adjectives, then the possible grammatical types (infinite in number) all fall under one of the following schemes.

Grammatical Type

1. $PN + V_1$
2. $PN + V_2 + PN$
3. $Adj^n + N + V_1$
4. $PN + V_2 + Adj^n + N$
5. $Adj^n + N + V_2 + PN$
6. $Adj^m + N + V_2 + Adj^n + N$

What needs explaining are the semantic functions to the right of each production rule. For this purpose it will be desirable to look at each production rule and then to consider some examples of sentences generated by this grammar. The intuitive idea is that we define a valuation function v over V, and as is standard in model-theoretic semantics, v takes values in some relational structure.

Suppose the speaker wants to say that John hit Mary. On the left we write the derivation and on the right the valuations.

1.	S	$v(S) = \text{True}$
2.	NP + VP	$v(NP) \subseteq \underbrace{v(VP)}$
3.	$NP + V_2 + NP'$	$v(NP) \subseteq \underbrace{v(V_2)}"v(NP')$
4.	$PN + V_2 + NP'$	$v(PN) \subseteq \underbrace{v(V_2)}"v(NP')$
5.	$PN + V_2 + PN'$	$v(PN) \subseteq v(V_2)"v(PN')$
6.	$John + V_2 + PN'$	$v(John) \subseteq \overbrace{\underbrace{v(V_2)}}"v(PN')$
7.	John + hit + PN'	$v(John) \subseteq \underbrace{v(hit)}"v(PN')$
8.	John + hit + Mary	$v(John) \subseteq v(hit)"v(Mary)$.

We could illustrate these ideas just as well by using a derivation tree rather than a derivation. In either case, the intuitively important point is that the valuation function v shows how a simple thought or idea can be carried through a derivation. In line (2), "v(NP)" already denotes John and "v(VP)" denotes the act of hitting Mary. With the semantics explicitly in front of us, a probabilistic mechanism for generating the actual utterance, as described in Suppes (1970), assumes its natural place. With high probability, NP, for example, will terminate either in a proper name or a description sufficient to discriminate the object v(NP) from immediate competitors for attention. Only with low probability will NP terminate in a much longer conceptually or perceptually redundant terminal string.

This last point needs expanding. To go outside our simple language, suppose John and Mary are walking, and John notices a spider close to Mary's shoulder. He says, "Watch out for that spider." He does not say, "Watch out for the black, half-inch long spider that has a green dot in its center and is about six inches from your left shoulder at a vertical angle of about sixty degrees." The principle that selects the first utterance and not the second I call the Principle of Minimal Discrimination. I return later to the problems associated with giving the principle a formally precise statement.

Let us return now to the semantic functions listed for each production rule. The first rule reads as follows:

$$v(S) = \begin{cases} \text{True} & \text{if } v(NP) \subseteq v(VP) \\ \text{False} & \text{otherwise,} \end{cases}$$

or put a slightly different way, still more Fregean in spirit,

$$v(S) = [v(NP) \subseteq v(VP)] \ ,$$

where, of course, the two possible values of $v(S)$ are *true* and *false*. The rest of the rules have a straightforward denotative interpretation. Thus, for Rule 2

$$v(VP) = v(V_1) \ ,$$

i.e., the set-theoretical semantic function is just the identity function. For Rule 3

$$v(VP) = \overset{\smile}{v(V_2)}"v(NP) \ ,$$

which defines a standard set-theoretical function for relations. The remaining four rules are even more obvious

4. $v(NP) = v(PN)$ Identity
5. $v(NP) = v(AdjP) \cap v(N)$ Intersection
6. $v(AdjP) = v(AdjP) \cap v(Adj)$ Intersection
7. $v(AdjP) = v(Adj)$ Identity .

One point should be emphasized. I am not claiming that the set-theoretical semantic functions of actual speech are as simple as these. Consider Rule 5, for instance. Intersection is fine for *old dictators*, but not for *alleged dictators*. One standard mathematical approach to this kind of difficulty is to generalize the semantic function to cover the meaning of both sorts of cases. In the present case of adjectives, we could require that $v(AdjP)$ be a function mapping sets of objects into sets of objects. In this vein, Rule 5 would now be represented by

$$v(NP) = v(AdjP)"v(NP) \ .$$

Fortunately, generalizations of this kind that rule out the familiar simple functions as semantic functions do not seem to occur early in children's speech. Some tentative empirical evidence on this point is presented in Section 4.

In the formal definition given in the next section, I admit the possibility that a given production rule has more than one set-theoretical semantic function. Here is a simple example. We might want _diplomatic relations_ or _economic relations_ to denote as a two-word phrase, and not have a relatively abstract denotation for _relation_ intersected by the denotation of _diplomatic_ or _economic_. Of course, in our conception of the ultimately satisfactory semantics for English we may want to exclude phrases that are not single words denoting as a unit, but whatever the proper ultimate view may be, the present impracticality of insisting on only single words denoting irreducibly seems apparent to me. In many analyses the class of relational structures or models we must consider is broadened undesirably if words like _diplomatic_ and _relations_ must each denote separately.

3. Denoting Grammars

I turn now to formal developments. Some standard grammatical concepts are defined in the interest of completeness. First, if V is a set, V^* is the set of all finite sequences whose elements are members of V. The empty sequence, 0, is in V^*; we define $V^+ = V^* - \{0\}$. A structure $G = \langle V, V_N, P, S\rangle$ is a phrase-structure grammar if and only if V and P are finite, nonempty sets, V_N is a subset of V, S is in V_N and $P \subseteq V^* \times V^+$. Following the usual terminology, V_N is the nonterminal vocabulary and $V_T = V - V_N$ the terminal vocabulary. S is the start symbol or the single axiom from which we derive strings or words in the language generated by G. The set P is the set of production or rewrite rules. If $\langle \alpha, \beta\rangle \in P$, we write $\alpha \rightarrow \beta$, which we read: from α we may produce or derive β (immediately).

A phrase-structure grammar $G = \langle V, V_N, P, S\rangle$ is context-free if and only if $P \subseteq V_N \times V^+$, i.e., if $\alpha \rightarrow \beta$ is in P then $\alpha \in V_N$ and $\beta \in V^+$. These ideas may be illustrated by considering the simple language of the previous section. Although it is intended that N, PN, Adj, V, and V_2 be nonterminals in any application, we can treat them as terminals for purposes of illustration, for they do not occur on the left of any of the seven production rules. With this understanding

$$V_N = \{S, NP, VP, AdjP\}$$

$$V_T = \{N, PN, Adj, V_1, V_2\}$$

and P is defined by the production rules already given. It is obvious from looking at the production rules that the grammar is context-free, for only elements of V_N appear on the left-hand side of any of the seven production rules.

We now define derivations. Let $G = \langle V, V_N, P, S \rangle$ be a phrase-structure grammar. First, if $\alpha \rightarrow \beta$ is a production of P, and γ and δ are strings in V^*, then $\gamma\alpha\delta \underset{G}{\Rightarrow} \gamma\beta\delta$. We say that β is *derivable* from α in G, in symbols, $\alpha \overset{*}{\underset{G}{\Rightarrow}} \beta$ if there are strings $\alpha_1, \ldots, \alpha_n$ in V^* such that $\alpha = \alpha_1$, $\alpha_1 \underset{G}{\Rightarrow} \alpha_2$, $\ldots$, $\alpha_{n-1} \underset{G}{\Rightarrow} \alpha_n = \beta$. The sequence $\langle \alpha_1, \ldots, \alpha_n \rangle$ is a *derivation* in G. (Formally I shall define semantic structures or evaluation functions on derivations, but it is just as natural to use derivation trees. In view of the unique correspondence between derivations and derivation trees in the case of context-free languages, I shall occasionally draw tree diagrams and use the language of trees without introducing the relevant formal definitions.)

As the last purely grammatical concept, the language $L(G)$ generated by G is $\{\alpha : \alpha \in V_T^* \;\&\; S \overset{*}{\underset{G}{\Rightarrow}} \alpha\}$. In other words, $L(G)$ is all strings that are made up of terminal vocabulary and that may be derived from S.

We now go on to semantics proper by introducing the set Φ of set-theoretical functions. We shall let the domains of these functions be n-tuples of any sets (with some appropriate restriction understood to avoid set-theoretical paradoxes).

Definition 1. *Let* $\langle V, V_N, P, S \rangle$ *be a context-free grammar. Let* Φ *be a function defined on* P, *which assigns to each production* p *in* P *a finite, possibly empty set of set-theoretical functions subject to the restriction that if the right member of production* p *has* n *terms of* V, *then any function of* $\Phi(p)$ *has at most* n *arguments. Then* $G = \langle V, V_N, P, S, \Phi \rangle$ *is a* potentially denoting context-free grammar.

The simplicity and abstractness of the definition may be misleading. In the case of a formal language, e.g., a context-free programming language, the creators of the language must specify the semantics by defining Φ. Matters are much more complicated in applying the same idea of capturing the semantics by such a function for fragments of a natural language. Perhaps the greatest single problem in applying this idea is that of giving a straightforward set-theoretical interpretation of intensional contexts, especially to those generated by the expression of propositional attitudes of believing, wanting, seeking and so forth. I shall not attempt to deal with these subtle matters in the present paper.

How the set-theoretical functions in $\Phi(p)$ work has been illustrated in the preceding section; some empirical examples follow in the next section. The problems of identifying and verifying Φ even in the simplest sort of context are discussed there. In one sense the definition should be strengthened to permit only one function in $\Phi(p)$ of a [illegible] given number of arguments. The intuitive idea behind the restriction is clear. In a given application we try first to assign denotations at the individual word level, and we proceed to two- and three-word phrases only when necessary. The concept of such hierarchical parsing is familiar in computer programming, and a detailed example in the context of a question-answering program is worked out in a joint paper with Helene Bestougeff (1970). However, as the examples in the next section show, this restriction seems to be too severe for natural languages.

A clear separation of the generality of Φ and an evaluation function v is intended. The functions in Φ should be constant over many different uses of a word, phrase or statement. The valuation v, on the other hand, can change sharply from one occasion of use to the next. For this reason v is defined for a given derivation, not the whole grammar. In the formal definition, as opposed to the intuitive example given in the preceding section, it is necessary to introduce an explicit device for differentiating one NP, N, V, etc., from another, and so it is required that v be a partial function on $V_N \times \omega$, where ω is the set of natural numbers. The point of ω is to keep track of the occurrences of nonterminal vocabulary, so that, for instance, one occurrence of NP need not denote the same object as another. On the other hand, it is natural to require that in a given derivation each terminal word denote in all occurrences the same object.

In the remaining definitions in this section a context-free potentially denoting grammar $G = \langle V, V_N, P, S, \Phi \rangle$ is always assumed without explicit mention, unless the contrary is noted. I first define semantic structures for terminal vocabulary only, and then for nonterminal vocabulary relative to a given derivation. The final definition is for the general concept of denotation.

Definition 2. Let D be a nonempty set and v a partial function on V_T^+ such that

(i) If v is defined for α in V_T^+, it is defined on no subsequence of α;

(ii) If α is in the domain of v, then $v(\alpha)$ is an element of D, an n-ary relation on D, or a function from D^m to D^n for some m and n.*

Then $\mathcal{D} = \langle D, v \rangle$ is a semantic structure for $L(G)$.

We also say that v is a valuation function for $L(G)$. The concept defined here is obviously closely related to the idea of a semantic structure or a possible realization of a theory formulated in first-order predicate logic. The generality of assumption prohibits us from defining any powerful notions like those of truth or consequence at this point.

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*Inclusion in the domain of v of sets or functions constructed from D but higher in the natural hierarchy is actually needed in the detailed empirical analysis of the next section. Extension of this clause of the definition to cover these cases is straightforward.

For the next definition we need the concept of the n^{th} occurrence of a nonterminal word α in a derivation. For this purpose we introduce an occurrence function Q. Let $\delta = \langle\alpha_1,\ldots,\alpha_n\rangle$ be a derivation in G. We may regard δ as a sequence of words from V, rather than as a sequence of length n of sequences. The former point of view is convenient for counting purposes. In this case each term x_m of δ is an element α of V, and so we define Q_δ as a mapping from δ to $V_N \times \omega$ such that if $x_m = \alpha$ then $Q_\delta(x_m) = \langle\alpha,m\rangle$. It is not necessary to count occurrences of terminal vocabulary in a derivation, because, as already stated, it is assumed that their denotation is constant throughout a given derivation. Because the nature of the occurrence function Q is obvious, we shall refer rather informally to occurrence numbers of nonterminal words and like matters in the sequel.

Definition 3. *Let* $\delta = \langle\alpha_1,\ldots,\alpha_n\rangle$ *be a derivation in* G, *let* D *be a nonempty set and let* v *be a partial function on* $V_T^+ \cup (V_N \times \omega)$. *Then* $\mathcal{D} = \langle D,v\rangle$ *is a* semantic structure *for* δ *if and only if:*

(i) $\mathcal{D} = \langle D,v|V_T^+\rangle$ *is a semantic structure for* L(G), (*where* $v|V_T^+$ *is the partial function* v *restricted to the domain* V_T^+),

(ii) *If* $\langle\alpha,m\rangle$ *is in the domain of* v *then* $v(\alpha,m)$ *is an element of* D, *an n-ary relation on* D, *or a function from* $D^{m'}$ *to* D^n *for some* m' *and* n.

I turn now to the basic definition of denoting. Because of the syntactic ambiguity of expressions derived in a context-free grammar, the fundamental object that denotes is taken to be a pair $\langle\beta,\delta\rangle$ where β is a terminal string and δ is a derivation of β. I deliberately refrained from saying that β is a sentence of $L(G)$, because in the applications considered in the next section and others planned for the future, restricted grammars for noun phrases or verb phrases are considered, and in such cases, β would ordinarily not be a sentence.

Definition 4. *Let* $\beta \in V_T^+$, *let* $\alpha_1 \in V_N$, *let* $\delta = \langle\alpha_1,\alpha_2,\ldots,\alpha_m\rangle$ *be a derivation of* β *in* G, *and let* $\mathcal{D} = \langle D,v\rangle$ *be a semantic structure for* δ. *Then* $\langle\beta,\delta\rangle$ *denotes* X *in* $\mathcal{D}$ *if and only if*:

(i) $v(\alpha_1,1) = X$,

(ii) *If* α_h *is derived from* α_{h-1} *by the production* $p = \gamma \rightarrow \theta$ *in* P *applied to the* n_0^{th} *occurrence of* γ *in* δ *and if* $\langle\gamma,n_0\rangle$ *is in the domain of* v, *then for some* φ *in* $\Phi(p)$

(a) $$v(\gamma,n_0) = \varphi(v(\tau_{k_1},n_{k_1}),\ldots,v(\tau_{k_1},n_{k_q}))$$

where $n_0,n_{k_1},\ldots,n_{k_q}$ *are the occurrence numbers in* D *of the words* $\eta_1\tau_{k_1},\ldots,\tau_{k_q}$ *in* V, *and* $\langle\tau_{k_1},\ldots,\tau_{k_q}\rangle$ *is a subsequence of* γ;*

(b) *if* $\psi(\ldots,v(\gamma,n_0),\ldots)$ *is the denotation of* α_{m-1}, *then*

$$\psi(\ldots,\varphi(v(\tau_{k_1},n_{k_1}),\ldots,v(\tau_{k_q},n_{k_q})),\ldots)$$

is the denotation of α_m,

(iii) *On the other hand, if* $\langle\gamma,n_0\rangle$ *is not in the domain of* v, *then the denotation of* α_m *is the same as the denotation of* α_{m-1}.

This definition may be looked upon as defining recursively the denotation of each line of a derivation. If we wish to make the denotation function ψ notationally explicit for line 1, we have

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*For uniformity and therefore simplicity of notation, occurrence numbers have been assigned to terminal as well as nonterminal vocabulary, and v has been defined over $V_T^+ \times \omega$ rather than V_T^+ alone, but vacillation on this point is harmless, and I shall follow whichever notation is more convenient in a given context. On the other hand, it is essential that v be defined on $V_N \times \omega$, not V_N alone.

$$v(\alpha_1,1) = \psi(v(\alpha_1,1)) = X .$$

I remarked earlier after the first characterization of semantic structures that further assumptions were needed to define truth for $L(G)$. Indeed, it is important to emphasize that often truth is not the fundamental concept, in fact, it is usually not, in the case of programming languages. All the same, I accept completely the importance of the concept of truth for a wide variety of uses of language. It may be instructive to see how the definition of truth is given as a special case of Definition 4 for the simple language of the preceding section.

In the standard definition of truth for sentences of first-order predicate logic, recursion on the basic properties of sentential connectives and quantifiers forms the core of the characterization. We need something similarly "concrete" to use as a basis for an appropriate truth definition for other languages. This is a simple matter for the language of the preceding section. Using Definition 4, we say that if β is a sentence of $L(G)$ and δ is a derivation of β from S, then $\langle\beta,\delta\rangle$ is true if and only if $v(S,1) = T$ and in the case of the mandatory line (2)

$$\psi(v(NP,1),v(NP,1)) = \begin{cases} T & \text{if } v(NP,1) \subseteq v(VP,1) , \\ F & \text{otherwise} , \end{cases}$$

and the rest of the details follow from what has already been said about the language. I do note that in defining truth I have included the two distinguished objects T and F in D, the domain of the semantic structure. The characterization of line (2) is needed to distinguish truth from falsity. The remaining set-theoretical functions in Φ have already been described in Section 2. There is, of course, nothing sacred about T and F, or the symbols denoting them. I could just as well have used the numbers 1 and 0, which is often done.

I emphasized at the beginning of this paper that the extensional semantic theory developed here is not adequate for a proper account of the expression of propositional attitudes or modalities. I have deliberately kept the theory extensional and therefore too simple in order to have a less complex setup for our first semantic analyses of children's speech, which I discuss next.

4. Noun-Phrase Semantics of Adam I

In Suppes (1970) I proposed and tested a probabilistic noun-phrase grammar for Adam I, a well-known corpus of the speech of a young boy (about 26 months old) collected by Roger Brown and his associates--and once again I wish to record my indebtedness to Roger Brown for generously making his transcribed records available for analysis. Eliminating immediate repetitions of utterances, we have a corpus of 6109 word occurrences with a vocabulary of 673 different words and 3497 utterances. Noun phrases dominate the corpus. Of the 3497 utterances, we have classified 936 as single occurrences of nouns, another 192 as occurrences of two nouns in sequence, 147 as adjective followed by noun, and 138 as adjectives alone. The context-free grammar for the noun phrases of Adam I has seven production rules and the theoretical probability of using each rule in a derivation is also shown, for purposes of later discussion. From a probabilistic standpoint the grammar has five free parameters: the sum of the a_i's is one, so the a_i's contribute four parameters and $b_1 + b_2 = 1$, whence the b_i's contribute one more parameter. To the right are also shown the main set-theoretical functions which make the grammar potentially denoting. These semantic functions, as it is convenient to call them in the present context, are discussed extensively below. I especially call attention to the semantic function for Rule 5, which is formally defined below.

Noun-Phrase Grammar for Adam I

Production Rule	Probability	Semantic Function
1. NP → N	a_1	Identity
2. NP → AdjP	a_2	Identity
3. NP → AdjP + N	a_3	Intersection
4. NP → Pro	a_4	Identity
5. NP → NP + NP	a_5	Choice function
6. AdjP → AdjP + Adj	b_1	Intersection
7. AdjP → Adj	b_2	Identity

As I remarked in the earlier article, except for Rule 5, the production rules seem standard and an expected part of a noun-phrase grammar for standard English. The new symbol introduced in V_N beyond those introduced already in Section 2 is Pro for pronoun; inflection of pronouns has been ignored. On the other hand, the special category, PN, for proper nouns is not used in the grammar of Adam I.

The basic grammatical data are shown in Table 1. The first column gives the types of noun phrases actually occurring in the corpus in decreasing order of frequency. To shorten notation, some obvious abbreviations are used: A for Adj, P for Pro. The grammar defined will generate an infinite number of types of utterances, but, of course, all except a small finite number have a small probability of being generated. The second column lists the numerical observed frequencies of the utterances (with immediate repetition of utterances deleted from the frequency

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Insert Table 1 about here

TABLE 1

Probabilistic Noun-Phrase Grammar for Adam I

Noun phrase	Observed frequency	Theoretical frequency	Stand. semantic function
N	1445	1555.6	1445
P	388	350.1	388
NN	231	113.7	154
AN	135	114.0	91
A	114	121.3	114
PN	31	25.6	
NA	19	8.9	
NNN	12	8.3	
AA	10	7.1	
NAN	8	8.3	
AP	6	2.0	
PPN	6	.4	
ANN	5	8.3	
AAN	4	6.6	
PA	4	2.0	
ANA	3	.7	
APN	3	.1	
AAA	2	.4	
APA	2	.0	
NPP	2	.4	
PAA	2	.1	
PAN	2	1.9	

count). The third column lists the theoretical or predicted frequencies when a maximum-likelihood estimate of the five parameters is made (for details on this see the earlier article). The impact of semantics on these theoretical frequencies is discussed later.

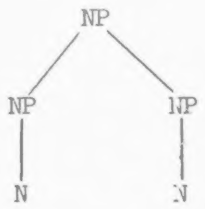
The fourth column lists the observed frequency with which the "standard" semantic function shown above seems to provide the correct interpretation for the five most frequent types. Of course, in the case of the identity function, there is not much to dispute, and so I shall concentrate entirely on the other two cases. First of all, if the derivation uses more than one rule, then by standard interpretation I mean the derivation that only uses Rule 5 if it is necessary and that interprets each production rule used in terms of its standard semantic function. Since none of the derivations is very complex, I shall not spend much time on this point.

The fundamental ideas of denoting grammars as defined in the preceding section come naturally into play when a detailed analysis is undertaken of the data summarized in Table 1. The most important step is to identify the additional semantic functions if any in $\Phi(p)$ for each of the seven production rules. A simple way to look at this, I believe, is to examine the various types of utterances listed in Table 1, summarize the production rules and semantic functions used for each type, and then collect all of this evidence in a new summary table for the production rules.

I therefore shall now discuss the types of noun phrases listed in Table 1 and consider in detail the data for the five most frequent.

Types N and P, the first two, need little comment. The identity function, and no other function, serves for them. It should be clearly understood, of course, that the nouns and pronouns listed in these first two lines--a total of 1833 without immediate repetition--do not occur as parts of a larger noun phrase. The derivation of N uses only P1 (Production Rule 1), and the derivation of P uses only P4.

The data on type NN are much richer and more complex. The derivation is unique; it uses P5 then P1 twice, as shown in the tree. As before, the semantic function for P1 is just the identity function, so all the analysis of type NN centers around the interpretation of P5. To begin with, I need to explain what I mean by the choice function shown above as the standard semantic function of P5. This is a set-theoretical function of A and B that for each A is a function selecting an element of B when B is the argument of f. Thus



$$\varphi(A,B) = f_A(B) .$$

Here I have used 'A' rather than an individual variable to make the notation general, but in all standard cases A will be a unit set. (I emphasize again that I do not distinguish unit sets from their members.) A standard set-theoretical choice function, i.e., a function f such that if B is in the domain of f and B is nonempty then $f(B) \in B$, is a natural device for expressing possession. Intuitively, each of the possessors named by Adam has such a function and the function selects his (or hers or its) object from the class of like objects. Thus *Daddy chair* denotes that chair in the class of chairs within Adam's purview that belongs to or is used especially by Daddy. If we restrict our possessors to individuals, then in terms of the semantic structure $\mathcal{D} = \langle D,v\rangle$, $\varphi(A,B)$ is just a partial function from $D \times \mathcal{P}(D)$ to D, where $\mathcal{P}(D)$ is the power set of D, i.e., the set of all subsets of D.*

The complete classification of all noun phrases of type NN is given in Table 2. As the data in Table 2 show, the choice function is justly labeled the standard semantic function for P5, but at least four other semantic functions belong in $\Phi(P5)$. One of these is the converse of $\varphi(A,B)$ as defined above, i.e.,

Insert Table 2 about here

$$\breve{\varphi}(A,B) = f_B(A) ,$$

which means the possessor is named after the thing possessed. Here are examples from Adam I for which this interpretation seems correct: *part trailer* (meaning *part of trailer*), *part towtruck*, *book boy*, *name man*, *ladder firetruck*, *taperecorder Ursula*. The complete list is given in Table 2.

The third semantic function is a choice function on the Cartesian product of two sets, often the sets' being unit sets as in the case of

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*Other possibilities exist for the set-theoretical characterization of possession. In fact, there is an undesirable asymmetry between the choice function for *Adam hat* and the intersection function for *my hat*, but it is also clear that $v(\textit{my})$ can in a straightforward sense be the set of Adam's possessions but $v(\textit{Adam})$ is Adam, not the set of Adam's possessions.

TABLE 2

Semantic Classification of Noun Phrases of Type NN*

Choice function

Adam checker
Adam hat
Adam bike
Moocow tractor
Catherine dinner
Newmi book
Daddy briefcase
Adam book
Daddy chair
Mommy tea
Tuffy boat
Adam tractor
Judy buzz
Ursula pocketbook
Daddy name
Daddy Bozo
Daddy name
Catherine Bozo
Adam glove
Adam locomotive
Daddy racket
Adam pencil
Joshua foot
Robie nail
Train track
Daddy suitcase
Adam suitcase
Adam doggie
Choochoo track
Adam water
Ursula car
Hobo truck
Doctordan circus
Daddy paper
Cromer coat
Adam pillow
Adam pillow
Dan circus

Adam horn
Adam hat
Adam pillow
Moocow truck
Car mosquito
Newmi bulldozer
Adam book
Adam paper
Daddy tea
Tuffy boat
Adam pencil
Tuffy boat
Judy buzz
Ursula pocket
Daddy name
Daddy Johnbuzzhart
Adam light
Monroe suitcase
Adam ball
Daddy racket
Adam racket
Joshua shirt
Adam busybulldozer
Adam busybulldozer
Adam Daddy
Cromer suitcase
Daddy suitcase
Adam doggie
Daddy Adam
Ursula water
Adam house
Doctordan circus
Joshua book
Adam Cromer
Adam pencil
Mommy pillow
Daddy pillow
Doctordan circus

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*Whenever the type NN appeared in the context of a longer utterance, the entire utterance is printed.

Adam ladder
Adam mouth
Doctordan circus
Adam horn
Adam piece
Adam playtoy
Doggie car
Adam book
Adam shirt
Adam ball
Cromer suitcase
Adam letter
Adam firetruck
Bambi wagon
Like Adam bookshelf
Pull Adam bike
Write Daddy name
Hit Mommy wall
Hit Adam roadgrader (?)
Spill Mommy face
Bite Cromer mouth
Hit Mommy ball
Get Adam ball
Write Cromer shoe
Sit Missmonroe car
Walk Adam Bambi
Adam Panda march (?)
Oh Adam belt
Adam bite rightthere (?)
Fish water inhere
Put Adam bandaid on
Put Missmonroe towtruck (?)
Mommy tea yeah
Adam school tomorrow
Daddy suitcase goget it
Take off Adam paper
No Adam Bambi
That Adam baby
Powershovel pick Adam dirt up

Adam mouth
Daddy desk
Adam sky
Adam baby
Adam candy
Kitchen playtoy
Man Texacostar (?)
Adam paper
Adam pocketbook
Daddy suitcase
Adam suitcase
Adam pencil
Adam firetruck
See Daddy car
Give doggie paper
Read Doctor circus
Write Daddy name
Hit Mommy rug
See Adam ball
Bite Mommy mouth
Bite Ursula mouth
Take Adam car
Sit Adam chair
Sit Monroe car
Walk Adam Bambi
Going Cromer suitcase
Doggies tummy hurt
Yeah locomotive caboose
Adam shoe rightthere
Take lion nose off
Pick roadgrader dirt (?)
Put Adam boot
Adam pencil yeah
Becky star tonight
Adam pocket no
Big towtruck pick Joshua dirt up
Look Bambi Adam pencil
Break Cromer suitcase Mommy
Where record folder go

Converse of choice function

Part trailer
Book boy
Ladder firetruck
Part head
Foot Adam
Car train
Taperecorder Ursula

Part towtruck
Name man
Record Daddy
Part game
Track train
Part broom
Circus Dan

Speghetti Cromer
Part basket
Game Adam
Take piece candy
Excuseme Ursula part broom

Part apple
Piece candy
Time bed (?)
Paper kitty open

Choice function on Cartesian product

Pencil paper
Mommy Daddy
Mommy Daddy
Pencil roadgrader (?)
Busybulldozer truck (?)
Jack Jill come

Paper pencil
Towtruck fire
Record taperecorder
Jack Jill
Give paper pencil
Adam wipeoff Cromer Ursula

Intersection

Lady elephant
Lady Ursula
Toy train

Lady Ursula
Lady elephant
Record box

Identity

Pin Game
Daddy Cromer (?)
Doctor Doctordan

Babar Pig
Mommy Cromer (?)

Unclassified

Joshua home
Train train (Repetition?)
Dog pepper
Suitcase water
Doggie pepper
Daddy home (S)
Door book
Pumpkin tomato
Chew apple mouth (2)
Hit door head (2)
Hit head trash (2)
Show Ursula Bambi (2)
Look car mosquito (2)
Pick dirt shovel up (2)
Ohno put hand glove (2)

Pencil doggie
Adam Adam (Repetition?)
Kangaroo bear
Doggie doggie (Repetition ?)
Kangaroo marchingbear
Ball playtoy (?)
Pumpkin tomato
Put truck window (2)
Hit towtruck knee (2)
Make Cromer Doctordan (2)
Hurt knee chair (2)
Show Ursula Bambi (2)
Daddy Daddy work (Repetition?)
Mommy time bed
Time bed Mommy

Note.--230 utterances of type NN are shown instead of the 231 shown in Table 1, because one of the 231 was incorrectly classified as NN.

Mommy Daddy. Formally, we have

$$\varphi(A,B) = f(A \times B) ,$$

and $f(A \times B) \in A \times B$. Other examples are Daddy Adam and pencil paper. The frequency of use of this function is low, however--only 12 out of 230 instances according to the classification shown in Table 2.

The fourth semantic function proposed for $\Phi(P5)$ is the intersection function,

$$\varphi(A,B) = A \cap B .$$

Examples are lady elephant and lady Ursula. Here the first noun is functioning as an adjective.

The fifth semantic function, following in frequency the choice function and its converse, is the identity function. It seems clear from the transcription that some pairs of nouns are simply being used as a proper name or a simple description, even though each noun is used in other combinations. (By a simple description I mean a phrase such that no subsequence of it denotes (see (i) of Definition 2).) Some examples are pin game and Daddy Cromer.

November 11th, 1970

Comments on: "The problem of the semantics of mass terms in English,"
by Julius Moravcsik.

From: Elisabeth Traugott, Linguistics, Stanford.

The linguistically most interesting point raised in this paper seems to me to be that "mass" operates not only for nouns, but also for verbs and adjectives. I wonder whether it will actually be possible to set up criteria of adequacy for the semantics of mass terms until the pervasiveness of "mass" can be considered, rather than "mass" in subject position or else in predicate position. I have no solution in mind, but it seems to me that the following areas need a lot more investigation:

i) To what extent is non-punctuality a property associable with or even identifiable with mass, e.g. *He drinks water* is a durative sentence, *He drinks the water* is punctual; in the first *water* is a true mass noun, in the second *a bit of water* (see H.V. King, English Language Institute Papers 1 and 2, 1967, 1968)?

ii) To what extent do selectional constraints operate between all N, V, A in a sentence? Does mass operate somewhat like negation with a sentential domain? The difference between the cumulativeness of *red* in *red ink* vs. the non-cumulativeness of *red* in *This ink is red* discussed on p.11 is accountable for in terms of the fact that the *red ink* derives from the generic sentence *ink is red* (generic and non-punctual) while *this ink is red* is non-generic and punctual, and is not the source for *red ink* (it *is* the source for *this red ink*).

iii) The *red ink* problem brings me to wonder what exactly the reltionship between genericness and mass is. Is mass a special subtype of generic (a lexicalised feature of genericness perhaps)?

iv) How is it that mass nouns can be used with the *bit of* sense, and count nouns can too? Such locutions as *What a boy!* involve quantification of qualities of boyishness and have similar semantic interpretations as such locutions as *What water!* (at least in one interpretation).

Some specific details:

p.1. [-count] is *not* contrasted with all abstract terms in Chomsky, *Aspects* p.82. He gives the following rule :

[-Count] → [±Abstract]

p.3. Could the *heavy-light* problem not be accounted for in terms of the fact that *heavy* is unmarked and [+Polar] (in Bierwisch's sense), while *light* is the marked member and [-Polar]. No term that is [-Polar] allows for mass interpretation in Quine's sense; surely this follows from the fact that [-Polar] by definition means "misses the norm" and is negative.

p.11 As indicated above the *red ink* vs. *This ink is red* problem is a pseudo-problem since they have distinct syntactic sources.

On the Insufficiency of Surface Data for the Learning of Transformational Languages

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November 20-21, 1970

Abstract

Identifiability in the limit is studied, with special reference to transformational languages on a given base. First a theorem is proved which gives necessary conditions for a class of languages to be identifiable in the limit. With added assumptions, these conditions become sufficient for identifiability. The question of whether the class of transformational languages on a fixed context-free base is identifiable is studied. Counter-examples, that is context-free grammars for which the set of transformational languages is not identifiable, are exhibited. One of these examples involves no deletion, the use of the transformational cycle and only binary transformations.

If one claims to understand a particular phenomenon, then, in order to check that claim, we must decide what it is to understand that phenomenon. Another way of saying this is that we must decide for what the claimant is accountable.

Note that what the theorizer says about his accountability is not necessarily a criterion. For if he says that he is explaining this but not that, it may nevertheless be the case that we cannot understand this without understanding that.

In particular, suppose a claim is made that one understands language competence. That is, one puts forth a theory of linguistic competence. We can then ask whether this theory is accountable for an explanation of the acquisition of language.

We do not argue that a theory of linguistic competence must include a theory of language acquisition. It does seem possible that one can understand language and its use by humans without understanding how it was acquired.

But matters are not so simple. Suppose we agree that language competence is acquired. That is, early in a child's life he cannot speak and later on he can. Suppose, in addition, that we have a theory of mechanism which we believe is as powerful as anything the human mind could be. Then, if this mechanism can be shown incapable of acquiring language as conceived by the theory of linguistic competence, then there is a lapse in our understanding for which we must account. The present work is undertaken in the spirit of demonstrating and illustrating this gap in our understanding.

Identifiability in the Limit

A grammar is a general rewriting system (see, for example, Hopcroft and Ullman, 1969). If G is a grammar, then L(G) is the language generated by G.

Gold (1967) defined a notion of learnability of language in the following way. Suppose time is discrete and at each time the learner receives a piece of information about the language which he is learning. At each time the learner guesses the identity of the language. A class of languages is said to be identifiable in the limit if there is an algorithm such that, given any language in the class, there is a finite time after which the guesses will all be correct.

Gold considered various methods of information presentation. In text presentation, only positive instances of sentences in a language are allowed. In informant presentation, negative instances (identified as such) are allowed. Gold showed that informant presentation allowed a far wider class of languages to be identified. However, there is some reason to consider text presentation as a better model of the actual situation faced by the child as he acquires language. At first sight, at least, there appears to be a far larger number of positive instances given to a child. Also, what empirical evidence there is (Brown and Hanlon, 19) supports this view.

An information sequence I(L) of a language L is a sequence of sentences of L such that every sentence of the language appears in the sequence. I(L) denotes the set of all information sequences of L. Let $I(L) = a_1, a_2, \ldots$ be an information sequence. Then a sample of I is $S_t(I) = \{a_1, \ldots, a_t\}$. Thus a sample is an unordered set.

A learning device D is a function from the set of samples (that is, the set of finite sub-sets of Σ^*) into the set of grammars in some class C. We conceive of $D(S_t(I))$ as being the guess that D makes at time t when presented with the information sequence I.

We say that the class of languages L(C) is identifiable in the limit if there is an effective function D such that for any $G \in C$ and any information sequence $I(L(G))$ there exists a τ such that $t > \tau$ implies both

$$\text{a) } D(S_t(I)) = D(S_\tau(I)),$$

$$\text{b) } L(S_\tau(I)) = L(G).$$

Gold has shown that none of the usual classes of languages are identifiable in the limit. This includes the finite-state and context-free grammars. In fact, any class of languages which includes all the finite languages and at least one infinite language is not identifiable.

This result leaves us in the following dilemma. If none of the classes of languages normally taken as models for natural languages can be identified, how then is language learned? Before attempting an answer to this question, we will first find it useful to characterize some identifiable languages in the following way. We assume that a class of languages only includes recursive languages.

THEOREM. If a class of languages K is identifiable in the limit then K does not contain an infinite subset of languages $K' = \{L_0, L_1, L_2, \ldots\}$ such that

1) $L_0 = \bigcup_{i=1}^{\infty} L_i$, and

2) for every finite subset F of L_0, there are an infinite number of $L_i \in K'$ such that $F \subseteq L_i$.

PROOF. We show that if K contains such a K' then K is not identifiable. Since it is well known that a superset of a non-identifiable class is not identifiable, it will be sufficient to show that K' is not identifiable.

We construct an information sequence $I(L) = a_1, a_2, \ldots$ of elements of L_0 such that an infinite number of changes will be made in the guessed language. Let D be a function from samples into a class of grammars such that K' is identified in the limit by D. (We suppress I(L) when the information sequence is fixed).

To construct the sequence I(L), first present a finite sequence $T_1 = a_1, a_2, \ldots, a_{t_1}$ such that $L(D(S_{t_1})) = L_1$, where $L_1, L_2, \ldots$ is an enumeration of $K' - \{L_0\}$. That is, after this sequence the learning device guesses a grammar for L_1. We know that such a sequence exists because D identifies K'. We next want to present a sequence that will make D guess another language. But we have to make sure that every sentence in L_0 appears in the information sequence. We can effectively enumerate the sentences of L_0, obtaining $b_1, b_2, \ldots$. After each of the sequences which causes D to change its guess we will add the next sentence of this enumeration, thus assuring that every sentence in L_0 appears at least once in the information sequence. Thus I(L) starts with T_1, b_1. Let $i_1 = 1$.

Now by assumption 2, S_{t_1+1} is a subset of infinitely many L_i. Let i_2 be the smallest $i \neq 1$ such that $S_{t_1+1} \subseteq L_i$. Since S_{t_1+1} is finite and each L_i is recursive, there is an effective procedure for calculating i_2. Now let $T_2 = a_{t_1+2}, \ldots, a_{t_2}$ be a sequence of strings from L_{i_2} such that $L(D(S_{t_2})) = L_{i_2}$. Next we list b_2. Thus the information sequence up to t_2+1 is T_1, b_1, T_2, b_2.

We continue in this manner. The general rule is: after the sequence has been constructed up to time t_2+1, add a sequence of strings from L_{i_j} such that a grammar of L_{i_j} is guessed after that sequence, where L_{i_j} is the first language in the enumeration of the L_i which contains the sample up to time t_j+1 and such that for $1 \le k \le j$, $D(S_{i_k}) \neq D(S_{i_j})$, that is, the guessed grammar is not one of those guessed at an earlier time i_k. The reason we can always choose a new grammar whose language contains the sample is that property 2 holds.

In this manner we construct the sequence

$$I(L) = T_1, b_1, T_2, b_2, \ldots, T_i, b_i, \ldots .$$

At each time t_i a grammar is guessed which is different from the grammar guessed at all earlier t_j, $j \le i$. Thus by definition D does not identify K'. Thus we have shown that if K is identifiable, no such K' exists. This proves the theorem.

As far as we know, this theorem is new. The following examples illustrate the theorem.

Example 1. (Feldman et al, 1969). Let $L_0 = a^*b^*$.

For each i > 0, let

$$L_i = \bigcup_{j=1}^{i} a^j b^*,$$

where a^j means a sequence of j b's and $a^j b^* = \{a^j b, a^j bb, a^j bbb, \ldots\}$ as in regular language terminology.

Then $K = \{L_0, L_1, \ldots\}$ meets conditions 1 and 2 of the theorem and thus K is not identifiable in the limit.

Example 2. Let $K = \{L_1, L_2, \ldots\}$ where L_i is as in the preceding example. In other words, L_0 is excluded. Then K has no subset which satisfies the

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conditions of the theorem. This does not, of course, prove that K is identifable, but it turns out that it is. A successful algorithm is the following: Guess a grammar which generates the smallest language in K which is compatible with (i.e. generates) the sample to date. Eventually this will be the correct grammar.

Example 3. This example shows that a nested infinite sequence of sets $L_1 \subseteq L_2 \subseteq$ . . . is not necessary for non-identifiability. For any vocabulary T, enumerate the strings in T^*, obtaining $a_1, a_2, . . .$. Let $L_i = \{T^* - a_i\}$ for $i>0$ and let $L_0 = T^*$. The $K=\{L_0, L_1, . . .\}$ is not identifiable since it meets the conditions of the theorem. But there is no infinite nested sequence of sets in K.

Example 4. If $L_0=T^*$ is left out of K in the preceding example, K becomes identifiable. Enumerate the grammars and at each time pick the first compatible grammar.

Example 5. To see that condition 1 of the theorem may not be omitted, consider the languages L_i of example 1 and add a string c to each of them, obtaining $L_i' = L_i \cup \{c\}$. Since c is not in L_0, the union of the L_i is not equal to L_0. Thus $K = \{L_0, L_1', L_2', . . .\}$ does not meet condition 1. In fact, K is identifiable. Guess a grammar for L_0 until c appears and then guess a grammar for the smallest compatible language.

Example 6. To see that condition 2 of the theorem may not be omitted, let $L_0 = a^*b^*$ and let $L_i = a^ib^*$. Then $K = \{L_0, L_1, . . .\}$ does not meet condition 2 of the theorem, since, for example, {abb, aab} is a finite subset of L_0 which is not a subset of infinitely many of the L_i. In fact it is a subset only of L_0. K is identifiable by guessing

L_i if the first string presented is $a^i b^j$ and changing the guess to L_0 whenever a string of the form $a^k b^g$, $i \neq k$, is encountered.

The reason we have gone ever so many examples is to motivate the conjecture that, in fact, the conditions of the theorem are not only sufficient, but necessary, that is if $K' \subseteq K$ meeting conditions 1 and 2 does not exist, then K is identifiable. In all our examples where K' failed to meet conditions 1 and 2, it turned out to be identifiable. All the examples we have found in the literature conform to this hypothesis. In fact, we have proved the following, weaker, theorem.

THEOREM. If K is a class of recursive language such that there is an effective procedure for enumerating the elements of K, and if there is an effective procedure for deciding for any 2 grammars G_i, G_j of languages in K, whether $L_i \subseteq L_j$, then K is identifiable in the limit if it does not contain an infinite subset $K' = \{L_0, L_1, \ldots\}$ such that

1) $L_0 = \bigcup_{i=1}^{\infty} L_i$, and

2) for every finite subset F of L_0, there are an infinite number of $L_i \in K'$ such that $F \subseteq L_i$.

SKETCH OF PROOF. We construct an algorithm D which will identify any language in K. Enumerate the grammars for K obtaining $G_1, G_2, \ldots$. The information sequence is $a_1, a_2, \ldots$. At time t, D guesses a grammar from $A_t = \{G_1, \ldots, G_t\}$. First form the set $C_t \subseteq A_t$ of "compatible" grammars, that is, grammars which generate the strings $a_1, \ldots, a_t$. Next, form the set $M_t \subseteq C_t$ of minimal grammars, that is, $G_i \in C_t$ is minimal if there is no $G_j \in C_t$ such that $L(G_j) \subseteq L(G_i)$. Then D guesses that grammar in M_t which is first in the enumeration, that is, which has the smallest i.

Our assumption makes D effective. We show that eventually G_i is guessed when $L(G_i)$ is presented. Suppose that $L(G_i)$ does not contain an infinite subset. Then there is some time t' such that for all $t>t'$, no subset of $L(G_i)$ is in C_t. Thus, for each G_j, $j<i$, G_j will be eliminated from C_t for $t>t''$, as long as G_j is not a superset of G_i. Thus for $t>t''$, D guesses G_i. Thus we consider only L_0 such that L_0 contains an infinite number of languages L_1, L_2, ...

Clearly, $L_0 \supseteq \bigcup_{i=1}^{\infty} L_i$. Suppose $a \in L_0$ but $a \notin L_i$ for any L_i. But then when a appears, at time t, only grammars for L_0 will be in C_t. Thus D will guess a grammar for L_0. Thus we can consider only cases where $L_0 = \bigcup_{i=1}^{\infty} L_i$.

Suppose condition 2 does not hold, that is, there is a subset F of L_0 such that F is contained in only a finite number of the L_i. But then once F has been presented, there are only a finite number of grammars G_i which are compatible with L_0. Each of these (except for supersets of the correct language) is eventually eliminated from C_t, and thus M_t contains only the correct grammar, and D identifies the grammar. This proves the theorem.

The "recursive" and "enumeration" conditions will perhaps be necessary to prove the theorem, and are not very restrictive from our point of view, since they are met, for example by the set of context-sensitive languages. The condition that we hope to eliminate is the one which requires decidability of the subset problem. Our current proof requires this condition because the algorithm D must determine what languages in a finite set are minimal. It is an open problem whether this condition can be eliminated.

Transformational Grammars on a Universal Base

It has been known since Gold's orginal formulation that the classes of languages which are usually studied are not identifiable in the limit. This is true of the finite-state, context-free and context-sensitive languages. This result is an immediate corallary of our first theorem applied to the class of languages defined in Example 1 of the preceding section.

This result leads to an attempt to restrict the class of possible languages in such a way that the class is identifiable. It would be particularly insightful if this restriction could be done in a linguistically interesting way. A strong interpretation of one version of linguistic theory (Chomsky, 1965) is that there is a single universal context-free base, and every natural language is defined by a transformational grammar on that base. At first sight it might appear that if we fixed the base and considered the class of languages to be the set of transformational languages on the base, then, since all the languages were related by virtue of having a common base, this class of languages might be identifiable in the limit.

It is important to realize that we are suggesting the class of transformational languages on a given base, not the set of all transformational languages. That is, let B be a context-free grammar and T_i a finite set of transformations. Then we are considering the class of languages $K = \bigcup_i T_i(B)$, and not the class $\bigcup_B \bigcup_i T_i(B)$. This latter class is clearly not identifiable since it includes all the context-free languages, which may be obtained by taking the identity transformation on each base language.

Peters and Ritchie (1970) have shown that the set of transformational languages on a fixed base is equal to the set of recursively enumerable languages. Thus this set is not identifiable. However, it is still interesting to see whether we obtain identifiable classes of languages when we use only tranformational models of limited power.

In the following examples we will have to use some notation from transformational theory. When the transformations get a little complex and we want to be precise, we will use notation from the transformational model developed by Ginsburg and Partee (1969). The reader unfamiliar with these notions is referred to this paper. Here we only recall that a transformational rule is a pair consisting of an "analysis" or a "domain statement" and a "structural change" on that domain statement.

A Non-identifiable Class of Transformational Languages

If B is a context-free grammar, let T(B) be the set of transformational languages on B. We will exhibit a context-free grammar B such that T(B) contains all the finite languages on a vocabulary and an infinite language. Gold showed that such a "superfinite" class was not identifiable and such a result follows easily from our first theorem.

We take as the base the grammar B which has the following rules:

$S \rightarrow cS'$
$S' \rightarrow aS'$
$S' \rightarrow bS'$
$S' \rightarrow a$
$S' \rightarrow b$

where S is the starting symbol and {a,b,c} is the terminal vocabulary. Thus the generated language $L(B) = c(a,b)^*$. Now, to show that any finite language on {a,b} may be generated from B by a finite set of transformations, we will define the transformations.

Suppose $F=\{s_1,\ldots,s_n\}$ is a finite set of strings on $(a,b)^*$ and suppose $s_i = c,x_{i1}x_{i2}\ldots x_{in_i}$ where $x_{ij} = a$ or b. Then for each s_i we define the transformation T_i in the following way.

T_i: domain statement $D = c,x_{i1},\ldots,x_{in_i}$,

structural change $C = \phi, 1,\ldots,n_i$.

Note that ϕ is the symbol for the empty string. The effect of T_i is to erase the c from s_i, and to leave all other sentences untouched. Define the transformation

T_0: domain statement $D = c,S'$

structural change $C = \phi, \phi$.

T_o deletes any string in L(B) which has a c in it. Now to generate F we simply take the n+1 transformations $T_1,T_2,\ldots,T_n,T_0$ in that order, i.e., in particular, T_0 must apply last. Then the effect of $T_1,\ldots,T_n$ is to delete the c from each s_i in F. T_0 then deletes all strings except those in F. Thus F is the generated language.

Now, L(B) is also a transformational language on B since we can define a transformation T with domain statement c,S' and structural change ϕ,2, which simply deletes c from each string. The grammar consisting only of T thus generates $(a,b)^*$. Thus every finite language and at least one infinite language is in T(B), which is thus not identifiable in the limit.

A More Satisfying Non-identifiable Class of Transformational Languages

One reason that we are not happy with the preceding example is that it depends so heavily on deletion, and, in fact, filtering, that is, base sentences which never reach the surface. In our search for non-identifiable classes of transformational languages, we can use the first theorem which we proved. If we require that each base sentence correspond to only one surface sentence, then the base grammar must generate an infinite language (or else all languages in T(B) would be finite and thus the class would be identifiable). But if we do not want to use deletion (or filtering of sentences), then an infinite base language will yield an infinite transformed language. Thus we need classes of languages in which each language is infinite. The theorem tells us that if we find a class with certain properties then it is not identifiable in the limit.

The class of languages we will generate from a universal base is $K = \{L_0, L_1, \ldots\}$, where

$$L_0 = \{a^j cb^j \mid j = 1,2,\ldots\} \cup \{b^j a^{j+1} cb \mid j=1,2,\ldots\},$$ and for

$i > 0$, $L_i = \{a^j cb^j \mid j=1,2,\ldots\} \cup \{b^j a^{j+1} cb \mid j=1,2,\ldots i\}$. Clearly conditions 1 and 2 of the theorem hold, and K is not identifiable in the limit.

The base grammar B is defined by the following rules:

$$S \to aSb$$
$$S \to acb$$
$$S \to abc.$$

Note that the strings in L(B) can be classified according to whether the last rule applied yielded acb or abc. The former will yield all strings of the form $a^j cb^j$. No transformations will apply to these strings and thus they will account for the first part of each L_i. The other kind of string ends with a rule yielding abc. For the language L_0, every string of the form $a^{j+1}bcb^j$ will be mapped into the string $b^j a^{j+1} cb$, thus yielding the other strings in L_0. For the language L_i, every string of the form $a^{j+1}bcb^j$ will be mapped into $b^j a^{j+1} cb$ if $j \le i$, but if $j > i$ then the string will be mapped into $a^{j+1}cb^{j+1}$ which is already in L_i and thus nothing new will be added to the language. Thus for each L_i, i>0, a finite number of the "non-central c" strings will be mapped into a new string, and all the rest will be mapped into strings which were already directly generated by B. Note that L_i, i>0, is an ambiguous language since L_i contains strings which have 2 derivations.

We assume in this example the principle of the transformational cycle, that is, transformations first apply to the most deeply embedded S, then the next highest, and so on. Ginsburg and Partee write this ordering restriction into the definition of each transformation, but for simplicity we will take it as a meta-rule.

The transformations will operate in the following manner. Suppose we want to generate language L_i. First T_o operates by bringing a b in the most deeply embedded S up front in the next highest S-dominated sub-tree. Then T_1 brings this b and another b from the rear to the front in the next highest sub-tree. In other words, with each new transformation applied, an additional b is added to the front of the new (transformed) terminal string. Thus the ability to generate these kinds of strings in L_i. But if the phrase-marker on which the transformations are working has more than i S's, i.e., more than i a's and b's, then if this process continues a string with more than i b's in front will be in the language contrary to its definition. And if the transformations just stop applying, a sentence with a number of a's, then a number of b's, then more a's will be generated. This sentence is also not in L_i. Thus we apply the transformations $\bar{T}_i$. This transformation counts the number of b's at the front of the string, and as soon as this number becomes greater than i the entire string of beginning b's is shifted to the end of the sentence, thus producing a sentence already in the language (directly from the base) and not allowing any more transformations to apply.

The language L_i will be generated by a grammar with i+2 obligatory transformations, T_o, $T_1, \dots, T_i, \bar{T}_i$. Before we define these transformations, consider L_1 as an example. Let D be the domain statement and C the structural change.

T_o. D=aabcb. C = ③① - ② - ϕ - ④ - ⑤.

T_1. D=abaSbb C = ②⑤① - ϕ - ③ - ④ - ϕ - ⑥.

$\bar{T}_1$. D=abbaSbb C = ① - ϕ - ϕ - ④ - ⑤ - ⑥ - ⑦②③.

The operation of these transformations on the base phrase-marker P is shown in Figure 1. P_o,P_1 and $\bar{P}_1$ are the resulting phrase-markers after the application of T_0, T_1 and $\bar{T}_1$, respectively. Figure 2 attempts to diagram the example in another way.

The definitions of the needed transformations is as follows.

T_o. As above. For i>0,

T_i. D=ab^iaSbb. C = ②③...(i+1)(i+4)① - $\underbrace{\phi - \dots - \phi}_{i}$ - (1+2) - (1+3) - ϕ - (i+5).

$\bar{T}_i$. D=ab^{i+1}aSbb. C = ① - $\underbrace{\phi - \dots - \phi}_{i+1}$ - (i+3) - (i+4) - (i+5) - (i+6)②③ ... (i+2).

The language L_i, then, is generated by the transformations $T_0, T_1, \dots, T_i, \bar{T}_i$. It remains only to define the transformations for L_o. L_o is generated by the previously defined T_o together with T.

T. D= aXaSbb. C= ②⑤① - ϕ - ③ - ④ - ϕ - ⑥.

T accomplishes the same operation as T_i does, but without bound. That is, T_i raises the string of b's at the beginning of the string and adds to them one from the end, and it does this no matter how long the string of b's. A variable (X) was used for the first time in the definiton of T. This is also the first place in which we have departed from the Ginsburg and Partee model, because X was moved to a different position in the structural change, contrary to the Ginsburg and Partee assumption.

These grammars, then, generate the class K, which is thus a sub-set of the class of transformational languages on the fixed base B. But K is not identifiable in the limit. Thus L(B), the set of transformational languages on B, is not identifiable.

The properties of our grammar are interesting. First, we have not used deletion at all, and yet have obtained non-identifiablity. Also, we have applied the transformational cycle. All transformations are binary, that is, they analyze only 2 depths (of S's) down. Only one transformation applies to each S-dominated sub-tree.

Hamburger and Wexler (1970) investigated the possibility of identifying the transformational mapping when (base, surface) pairs were presented. With transformations with exactly the above properties (with one exception, to be discussed below), a positive answer was obtained: the mapping is identifiable. Thus, with very similar grammars we have found in one case that the languages are not identifiable with only surface information presented, but that they are identifiable when pairs of base and surface were presented.

The one exception involves restriction on "raising" in the Hamburger and Wexler study which were not made here, and on which, in fact, our grammars fail. If we could find an example of non-identifiable (in our sense, from surface information) languages which also met the raising restriction, or, equivalently, if we could eliminate the raising restriction from the set of assumptions in the base, surface pair case, then we could conclude formally that base information was necessary for the class of transformational languages on a universal base to be identifiable.

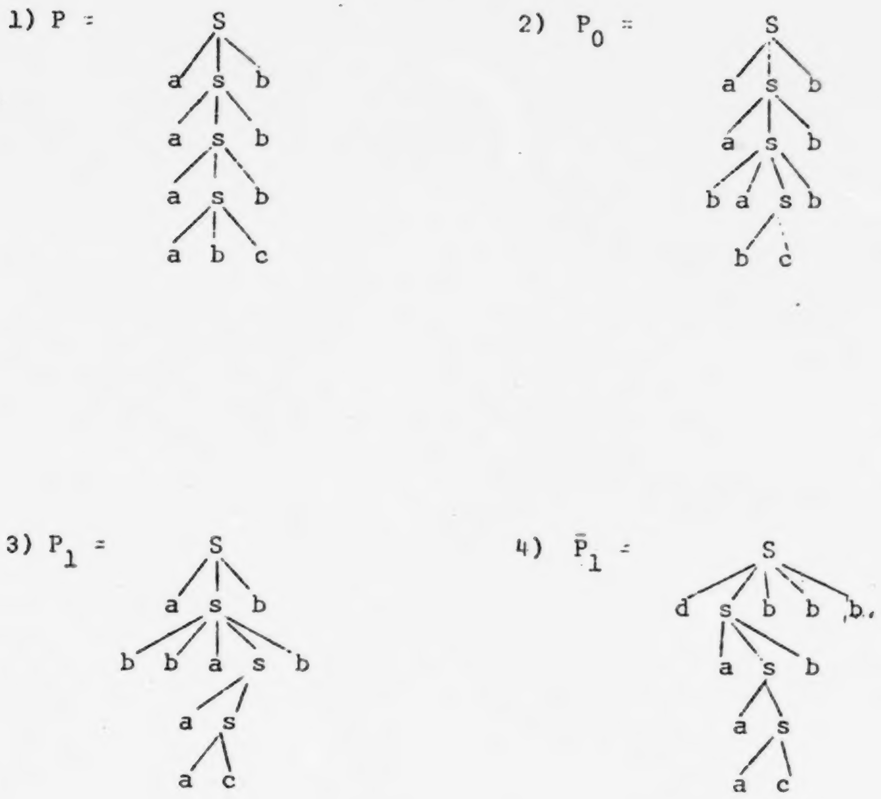
1) P =
2) P_0 =
3) P_1 =
4) $\bar{P}_1$ =

Figure 1. An Example of the Operation of the L_1 Transformations.

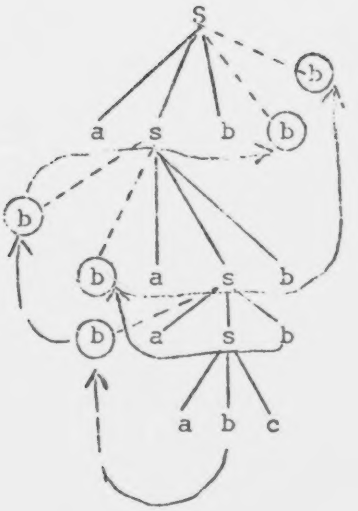
S
a
s
b
b
b
b
b
a
s
b
b
a
s
b
a
b
c

Figure 2. The Same Operations as in Figure 1

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